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Lessons Learned in the Use of Design/Information Technology in the Non-Residential Construction Industry

by

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Thesis

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Abstract

Lessons Learned in the Use of Design/Information Technology in the Non-Residential Construction Industry

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This thesis is the second part of a research initiative put forth by the National Institute of Standards and Technology. The goal of the research is to identify the benefits of utilizing Design and Information Technology (D/IT) in the non-residential sector of the U.S. construction industry. In part one, a statistical analysis of an entire database was conducted in an attempt to relate the use of D/IT to construction project performance. In this second part, six projects were selected from the database based on their "exemplary performance," for a detailed study of the relationship of the use of D/IT and project success in terms of project schedule growth, project cost growth, Recordable Incident Rate (RIR), rework, and project changes. The purpose is to document a series of "lessons learned."

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Chapter 1: Introduction

Many factors can be attributed to the success or failure of the construction process from the early planning stages through start-up and operations. Implementation of the latest technologies is one factor that generally helps the entire process to achieve success in categories such as cost savings, expediting the schedule, safety and quality. However, their improper use may lead to frustration and reductions in efficiency.

Some examples of the use of current technologies include the latest equipment, materials, or construction methods that enable workers to improve safety, quality and efficiency. Technology available for the improvement of management's efficiency consists of various computer applications such as an integrated database or 3D CAD modeling. These tools are herein referred to as design and information technologies (D/IT).

This research consists of identifying successful construction projects with a relative high use of D/IT and establishing a series of lessons learned by interviewing project personnel responsible for oversight of each individual project.

A NIST Initiative

This research is the second part of a three-part initiative put forth by the National Institute of Standards and Technology (NIST). The goal of the research is to evaluate the impacts of the use of D/IT within the non-residential sector of the U.S. construction industry. The data for this study comes from project information that is contained in the Construction Industry Institute (CII) Benchmarking and Metrics

database as well as through interviews with representatives from some of its member companies.

In the first part of the study, a statistical analysis was performed on a set of data taken from the CII database. The set consists of 297 U.S. construction projects completed in 1997 and 1998 that had reported on the use of D/IT. The purpose of the study was an attempt to quantify the value of using D/IT and to identify exemplary projects for further analysis. It includes baseline norms of industry trends and levels of use and norms of D/IT. It was completed by a graduate student at the University of Texas at Austin and is listed in the reference section (Koger, 1999).

The final part of the initiative is to summarize the data from the first two parts into a comprehensive technical report for submission to NIST. The final report will be available to the general public.

1.1 PURPOSE

The purpose of this thesis is to identify successful construction projects with a relatively high use of D/IT, as compared to other projects in the CII database, and to document a list of lessons learned.

1.2 SCOPE

The scope of this thesis was set by the requirements of NIST. It includes the evaluation of selected CII data for U.S. construction projects which has been collected over the past two years. The domestic requirement is exclusively for the project itself, whereas the design or planning may have been done internationally.

In defining a project's success for this study, the following criteria were considered:

1. Project cost growth
2. Project schedule growth
3. Safety
4. Rework
5. Project changes

The CII database consists of both owner and contractor submitted project data. Information was used from the latest questionnaires which includes what CII has labeled as "version 2.0" and "version 3.0." collected in '97 and '98 respectively. Data from the "version 1.0" questionnaire was not used as it did not contain reported use of D/IT. Data from the "version 4.0" questionnaire was not yet available. The total number for each category of projects considered in this study is shown:

Owner Projects	183
Contractor Projects	114
total-	297

The questionnaire addresses the use of the following D/IT:

Integrated databases
Electronic data interchange (EDI)
3D CAD modeling
Bar coding

Specific applications of each of the technologies can be seen in section 2.2 and are also in the CII Benchmarking and Metrics questionnaire shown in Appendix A.

1.3 OBJECTIVES

The research objective was to provide "lessons learned" for the uses of D/IT on successful construction projects. Furthermore, discussions with project personnel were conducted to solicit their input on the relative importance of the use of D/IT and the contributions they made to the project's success.

1.4 HYPOTHESIS STATEMENT

Proper understanding and use of D/IT has a positive impact on a project's success in terms of cost and schedule growth, as well as reductions in rework and change orders. Its use has no impact on project safety performance.

1.5 THESIS ORGANIZATION

Chapter 1 is an outline of the purpose, scope, and objectives of the research. Chapter 2 provides background information, and Chapter 3 is a discussion of how this research was conducted. An analysis of the CII data for the 297 projects is contained in Chapter 4. It contains performance trends relating to D/IT use.

The findings for each of the technologies are separated into Chapters 5 through 7. Each of these chapters contain a section on existing data, interview data, lessons learned, and future uses. The final chapter contains conclusions and recommendations for further research in this field.

Chapter 2: Background and Literature Review

The first step in this research was to gain an understanding of how design and information technology is employed in the construction process. To accomplish this, an extensive review of current literature was required. The purpose of reviewing background information and relevant literature was to gain a better understanding of the technologies and to learn what was discovered in the first part of the NIST initiative as well as in other similar research.

This chapter includes important background information regarding the construction industry, NIST, CII and its database, and a discussion of other publications relevant to this research. Also included is a definition of Design/Information Technology for the purpose of this study.

2.1 THE CONSTRUCTION INDUSTRY

The typical construction site contains many different types of workers using many different types of tools and equipment in a confined job location. Also included are management personnel, on both the owner and contractor teams, who often rely on computers and related software to help them plan and manage the work. The job usually has severe time and money constraints as well as a high regard for the safety of the workers and the quality of the finished product. All must work cooperatively and efficiently in order to attain project success.

The industry is second only to the health care sector in size, and currently comprises approximately 13% of the Gross National Product (NIST 1999). One area in which there is a tremendous opportunity for savings in both time and money is in

the employment of design and information technology. When done properly and on a timely basis, this implementation can provide a competitive advantage and preparation for future developments and advances.

2.2 THE NATIONAL INSTITUTE FOR STANDARDS AND TECHNOLOGY (NIST)

NIST was established by Congress to assist industry in the development of technology, to improve product quality, to modernize manufacturing processes, to insure product reliability, and to facilitate rapid commercialization of products based on new scientific discoveries. It is based in Gaithersburg, Maryland and also has an office in Boulder, Colorado.

One of the seven branches of NIST, the Building and Fire Research Laboratory, has a mission to enhance the competitiveness of U.S. industry and public safety performance prediction methods, measurement technologies and technical advances needed to assure the life cycle quality and economy of constructed facilities. Its products are used by those who own, design, construct, supply, and provide for the safety or environmental quality of constructed facilities. This research is being conducted under as a collaborative effort between NIST and CII.

2.3 THE CONSTRUCTION INDUSTRY INSTITUE

The Construction Industry Institute (CII) is comprised of approximately 85 owner and contractor members which are principally U.S. firms and governmental agencies. Its administrative headquarters are located in Austin, Texas at the

University of Texas at Austin. It is a research-oriented organization whose primary mission is:

> to improve the safety, quality, schedule, and cost effectiveness of the capital investment process through research and implementation support for the purpose of providing a competitive advantage to its members in the global marketplace.

2.3.1 History of the Construction Industry Institute

CII was founded in 1983 in Austin, Texas as part of the University of Texas at Austin's Bureau of Engineering Research. Its primary focus is improving the total quality and cost effectiveness of the construction industry through extensive research efforts. Its members include owners, engineers, and constructors who work with academia to address problems in the construction industry and look for ways to implement feasible solutions. Through its research, implementation, education and benchmarking and metrics programs, CII has improved the competitiveness of the North American construction industry in the global arena. CII started with a membership of 22 companies, but has since grown to include 85 member companies at the time of the start of this research.

2.3.2 CII Benchmarking and Metrics Database

One of the challenges faced by CII was to provide standardized measurements of performance in the construction industry. To solve this, CII developed a list of standard terms and definitions for project performance that enable comparisons to be

made between several different projects. These metrics are extremely important for the development of processes to measure project performance.

A Benchmarking and Metrics committee was created in 1993 to establish metrics that could be applied throughout the construction industry. The committee was also tasked with identifying "best practices" used by industry which would enhance project performance. The purpose of the program was to measure project performance and the use of "best practices" so that an assessment could be made of their relationship. Other objectives of the benchmarking program include educating the construction industry in best management practices and measuring the value of implementing those practices.

In order to develop the metrics database, CII developed a questionnaire to gather individual project data. The questionnaires are filled out by the member companies, and the data is processed by CII to create standardized CII defined project information such as project cost growth, or a design/information technology use index. The CII use and performance measures for the projects in this study include:

Design/information technology index
Project cost growth
Project schedule growth
Recordable incident rate (RIR)
Change cost factor
Rework cost factor

These terms are defined in Appendix B.

The questionnaire has been revised three times with the latest version labeled number 4.0. The contractor Version 3.0 is shown in appendix A as a sample.

The first questionnaire was sent to CII member companies in the spring of 1996. The criteria for a project's inclusion into the database is as follows:

The project was completed in the past three years

The project involved a minimum of 50,000 craft work-hours

Cost of the project was $2 million or more

A "normal" mix of craft hours

Companies providing the data were asked to provide a mix projects including those considered successful and problematic projects.

Version 2.0 of the questionnaire was distributed in early 1997. Version 3.0 was released in 1998 and had additional questions regarding the companies use of CII's best practices.

Version 2.0 and 3.0 data were used for this thesis. Version 1.0 data did not contain design/information technology use questions, and version 4.0 data are not yet available.

2.4 DESIGN/INFORMATION TECHNOLOGIES

Design/information technologies include a broad spectrum of computer-based technologies and software applications. The technologies included in this analysis are defined in Appendix B. As a basis for this study, the following applications were considered. The list is all of the applications addressed in the CII questionnaire.

1. Integrated database applications including:

   Facility planning

   Design/engineering

Procurement/suppliers

Material management

Construction operation/project controls

Facility operations

Administrative/accounting

2. Electronic data interchange (EDI) applications including:

    Purchase orders

    Material releases

    Design specifications

    Inspection reports

    Fund transfers

3. 3D CAD modeling applications including:

    Define/communicate project scope

    Perform plant walk-throughs

    Perform plant operability/maintainability

    Use as a reference during project/coordination meetings

    Work breakdown and estimating

    Plan rigging and crane operations

    Check installation clearances/access

    Plan and sequence construction activities

    Construction simulation/visualization

    Survey control and construction layout

Materials management, tracking and scheduling

Exchange information with vendors/fabricators

Track construction progress

Visualize project details or design changes

Record as-built conditions

Train construction personnel

Safety assessment/training

Plan temporary structures

Operations/Maintenance training

Turn-over design documents to the project owner

Start-up planning

4. Bar coding applications including:

Document control

Materials management

Equipment maintenance

Small tool/consumable material control

Payroll/timekeeping

During the interview process, the project managers were asked if they had used other applications which are not listed on the questionnaire.

One of the goals of the CII questionnaire is to determine the extent of use of various applications for the four listed design and information technologies. The person completing the questionnaire is asked to rate the level of use from one to five

depending upon the level of use for each application. There are also boxes to indicate that the application was not applicable or that the person was unaware of the particular use. Appendix C contains a sample of how the design/information technology use index is calculated.

2.5 LITERATURE REVIEW

In an effort to understand the technologies and their applications, a review of current information was conducted. Much of the information came from CII publications listed in the reference section. The internet is also a valuable source of current information, and there are many web sites that demonstrate the abilities of the latest technologies. Sites from which information was obtained for this thesis are listed in the reference section.

As mentioned earlier, this thesis is based on the second part of a three-part study. The first part is a data analysis performed by Kent Koger, a former Master's student at the University of Texas at Austin. His research provided a basis for this study and allowed for the identification of exemplary projects for further analysis. It documents the use of D/IT and assesses the relationships between use and project performance.

CII's Research Summary 125-1, Cost and Schedule Impacts of Information Management, also provided valuable information for this study. It showed that positive impacts to project schedule and cost could be made by implementing a sound information management strategy (CII RS 125-1, 1998). Also, the importance of a process-oriented approach in information management was stressed. One important

use of D/IT is the ability to simulate a method on a computer to provide a pre-test while incurring only minimal costs. This allows for better planning which leads to shortened cycle times, improved quality and safety, and better cost performance.

An extensive study of 3D CAD computer models in the construction industry was completed in November 1995 by CII (CII RS 106-1, 1995). It included a survey of CII Company's use and perceived benefits of 3D CAD, data collection of many projects, and a case study of a project in progress. The most widely reported applications reported were clearance checking and visualization of details. Two key findings from this survey relate to the way the model is developed and used. Its is crucial that the 3D model be properly maintained and held in an integrated database to gain maximum benefits from its use. Also, proper use of the model is absolutely necessary, or else it can have a detrimental effect on project performance. The survey also lists the three most significant impediments to the model's use as undetermined economic impact, resistance to change, and lack of training.

The complete findings are included in CII's Research Summary 106-1, 3D CAD Link (CII RS 106-1, 1995).

Chapter 3: Research Methodology

The first step for this research was to study the first part of the statistical analysis performed in part one of NIST/CII analysis. Next, a detailed study of the data set was performed to look for trends in the relationship between D/IT use and project performance. The results are provided in Chapter 4.

In an effort to better understand how the technologies are used to improve a construction project's performance, an analysis of individual projects was necessary. For this research, the initial goal was to choose a mix of approximately five "exemplary" projects, both owner and contractor, from the CII database for an in-depth study. The projects are labeled as exemplary based upon their relatively high reported use of D/IT and the following five performance metrics:

Project schedule growth

Project cost growth

Recordable Incident Rate (RIR)

Rework factor

Cost change factor

The definition for these metrics is provided in Appendix B.

Ultimately, three owner and three contractor projects were selected for analysis. The mix represents four different companies of which two are owner and two are contractor organizations. In keeping with CII's strict privacy policy, the projects are referred to as O1-O3 for owner projects and C1-C3 for contractor projects.

Since the goal of this research is to study the impacts of the uses of D/IT, it is important that the projects have a high reported use of D/IT. The projects that were considered had a Design/Information Technology use index in the top 25% as compared to other CII projects. A sample calculation of this index is shown in Appendix C.

3.1 DATA REVIEW

The performance metrics for the 297 owner and contractor projects were studied to look for trends in the relationship between D/IT use and project performance. The results show that there is better project performance on projects that have more use of D/IT. The details are discussed in Chapter 4.

The data are presented in Appendix D for contractor and owner projects respectively, and are sorted in descending order according to their D/IT use index. No value indicates that no data was reported for the metric, or it was not applicable to the project.

3.2 PROJECT SELECTION

The projects that were in the top 25% of the D/IT use index were considered as candidates for selection. For owner projects, this included project CII ID number O312, shown in italics, and those projects listed above it. For contractor projects, it was CII ID number C390, also shown in italics, and those shown above it.

Next, in order to select the projects to be studied, the five performance metrics identified for this study were examined for each project. These were compared to the mean and median values of the owner and contractor data. None of the projects with

a D/IT index in the top 25 percent had all five of the identified performance indicators above the CII mean. However, there were several projects to select from which were in the top 25percent in terms of the D/IT index and had above average values for three or four performance metrics.

Most of the projects in the top 25 percent of the D/IT use index category were in the heavy industrial category. Therefore, in an effort to obtain a homogeneous sample for analysis, the final projects selected were limited to this classification.

For final selection, it was desirable that the project have a broad use of D/IT in terms of using all of the listed technologies and many of their applications. Table 3-1 shows twenty projects selected for final consideration.

Table 3-1: D/IT Use* for Projects

CII ID	integrated database use	EDI use	3D CAD use	Bar Code use	D/IT use index
O370	X	X	X	X	5.75
O415	X	X	X	N	5.38
O143	X	X	X	X	5.24
O359	X	X	X	X	4.73
O139	N	X	X	N	4.31
O317	N	N	X	N	3.57
O117	N	N	X	X	2.92
O115	N	X	X	S	2.44
O362	X	X	N	N	2.44
C326	X	N	X	X	7.99
C176	X	X	X	S	7.58
C147	X	X	X	X	6.25
C214	X	X	X	X	5.30
C389	X	X	X	S	4.66
C394	X	X	X	X	4.55
C192	X	X	X	X	4.30
C153	X	X	X	N	4.09
C148	X	X	X	N	4.05
C138	X	N	X	N	3.54
C390	X	X	N	N	2.88

*Note: X = used, S = some use, N = no reported use

In this table, "some use" means that the company listed using only one or two of the applications for the particular category.

Ultimately, eleven of the twenty projects which had the highest and broadest use of D/IT were selected, and a request to gather further information was sent to representatives from each company. Although the goal was to study only five, it was assumed that some of the project representatives would not be available.

Six responses were received, each with a point of contact available to help with the study. Since there was an equal number of responses from owner and contractor representatives (3 each), a total of six people representing six different projects from four companies were interviewed. The projects all turned out to be chemical process plants and ranged from $41-173M in total project costs. Summary data are shown for the projects studied in Tables 3-2 and 3-3. The averages shown are for all of the owner and contractor data included in Appendix D.

Table 3-2: Performance Characteristics for Owner Projects

Performance Measure	O1	O2	O3	Owner Average
Cost growth	-15.7%*	-18.8%*	-5.5%	-4.3%
Schedule growth	-9.0%*	-7.2%	-8.8%*	3.1%
Rework cost factor	0.025	0.020	0.006*	0.046
Change cost factor	not shown	0.002*	not shown	0.039
RIR	0.80	1.45	0.73	2.10
D/IT use	5.24*	2.44*	5.38*	1.70

* indicates the number is in the top 25%

Table 3-3: Performance Characteristics for Contractor Projects

Performance Measure	C1	C2	C3	Contractor Average
Cost growth	-8.5%*	-11.1%*	1.4%	3.6%
Schedule growth	-46.4%*	3.0%	0.0%	2.3%
Rework cost factor	0.012*	0.047	0.041	0.028
Change cost factor	not shown	-0.063*	0.028	0.072
RIR	0.90	1.74	0.34*	2.07
D/IT use	4.30*	4.55*	5.30*	2.19

* indicates the number is in the top 25%

Also, the projects were all completed with cost-plus contracts with incentives, and all but one were located in Texas. The other was located in Mississippi.

3.3 DATA COLLECTION

The data collected for this research is from two different sources, the Construction Industry Institute benchmarking and metrics database and information obtained by interviewing company representatives.

3.3.1 CII Data

The data used to determine the exemplary projects was from CII's Benchmarking and Metrics database as well as from some of its completed project questionnaires. Only the data generated from CII's version 2.0 and 3.0 of the questionnaire was used.

3.3.2 Company Interviews

Once the exemplary projects were identified, permission was sought from company representatives to conduct on-site interviews with their project managers.

The interviews, which averaged about three hours each, were conducted to expand upon the D/IT questions contained in the CII database. The principal goals of the interviews were to determine:

- how the technologies were used
- what phase of the projects they were used
- if they are still being used within the company
- if their use has been increased or decreased
- what drove their use
- how they contributed to the success of the project
- their perceived benefits including any documented time or cost savings

Information was sought from the project managers to provide tangible benefits of the use of the technologies. The information could include items such as time and/or cost savings, reduction in rework rates, or lower RIR rates. In addition, this study also sought to identify uses of these technologies that may have had adverse impacts on project performance.

The interviewees were also asked to identify other factors that may have contributed to a project's success which they perceived as unrelated to the use of D/IT. The responses included:

- the project was a copy of a previous project
- the same management team was working on the project as the one that was just completed

- the communication/cooperation was very good
- the technical knowledge of the owner was superb
- the owner provided a "better than usual" project scope which remained relatively unchanged throughout construction

Ultimately a list of "lessons learned" related to D/IT for each application was compiled for inclusion into this report.

Chapter 4: Analysis of Existing Data

The data presented in Appendix D were analyzed to look for trends in the relationships between the level of use of D/IT and project performance. To compare those that reported a high use of D/IT and those who reported no use, the contractor and owner data were separated into three categories according to their D/IT use index. The categories include the top 10 percent of users, those that reported no use, and those in between, which are labeled the "middle" projects. The same was done for the top 25 percent of users, those reporting no use, and those in between. The results are shown in Tables 4-1 through 4-4 and summarized in Table 4-5. The averages shown are for all of the data in each of the listed categories. The corresponding standard deviation is shown below each average value.

Table 4-1: Contractor Data Comparisons for the Top 10% D/IT Use Index Projects

Project's D/IT use index category	Average D/IT Use index	Average Cost Growth	Average Schedule Growth	Average RIR	Average Change Cost Factor	Average Rework Factor
top 10% (11 projects)	**6.56**	**-7.5%**	**1.5%**	**1.54**	**-1.7%**	**3.7%**
st dev	*1.13*	*0.28*	*0.16*	*1.56*	*0.14*	*0.04*
"middle" (82 projects)	**1.91**	**10.9%**	**6.5%**	**3.21**	**12.4%**	**11.0%**
st dev	*1.21*	*0.27*	*0.20*	*4.57*	*0.14*	*0.34*
no use (21 projects)	**0.00**	**16.4%**	**6.3%**	**9.94**	**15.7%**	**8.4%**
st dev	*0.00*	*0.72*	*0.16*	*24.31*	*0.19*	*0.09*

Table 4-2: Contractor Data Comparisons for the Top 25% D/IT Use Index Projects

Project's D/IT use index category	**Average D/IT Use index**	**Average Cost Growth**	**Average Schedule Growth**	**Average RIR**	**Average Change Cost Factor**	**Average Rework Factor**
top 25% (28 projects)	**4.93**	**-1.4%**	**1.8%**	**2.29**	**2.3%**	**3.4%**
st dev	*1.56*	*0.20*	*0.16*	*2.64*	*0.10*	*0.03*
"middle" (65 projects)	**1.39**	**13.0%**	**7.8%**	**3.29**	**14.1%**	**14.3%**
st dev	*0.70*	*0.29*	*0.20*	*4.94*	*0.15*	*0.40*
no use (21 projects)	**0.00**	**16.4%**	**6.3%**	**3.72**	**15.7%**	**8.4%**
st dev	*0.00*	*0.72*	*0.16*	*3.41*	*0.19*	*0.09*

Table 4-3: Owner Data Comparisons for the Top 10% D/IT Use Index Projects

Project's D/IT use index category	**Average D/IT Use index**	**Average Cost Growth**	**Average Schedule Growth**	**Average RIR**	**Average Change Cost Factor**	**Average Rework Factor**
top 10% (18 projects)	**5.08**	**1.4%**	**-1.3%**	**2.43**	**7.7%**	**5.6%**
st dev	*1.05*	*0.15*	*0.17*	*4.06*	*0.05*	*0.09*
"middle" (112 projects)	**1.28**	**-1.6%**	**28.9%**	**3.58**	**9.7%**	**5.7%**
st dev	*0.92*	*0.16*	*1.52*	*7.84*	*0.26*	*0.04*
no use (53 projects)	**0.00**	**-0.3%**	**15.9%**	**5.10**	**8.6%**	**6.0%**
st dev	*0.00*	*0.12*	*0.38*	*6.19*	*0.15*	*0.04*

Table 4-4: Owner Data Comparisons for the Top 25% D/IT Use Index Projects

Project's D/IT use index category	Average D/IT Use index	Average Cost Growth	Average Schedule Growth	Average RIR	Average Change Cost Factor	Average Rework Factor
top 25% (46 projects)	**3.58**	**-2.8%**	**2.1%**	**2.14**	**12.8%**	**6.6%**
st dev	*1.45*	*0.16*	*0.17*	*3.63*	*0.36*	*0.07*
"middle" (84 projects)	**0.84**	**-0.2%**	**37.3%**	**4.14**	**7.5%**	**5.0%**
st dev	*0.48*	*0.15*	*1.75*	*8.80*	*0.13*	*0.04*
no use (53 projects)	**0.00**	**-0.3%**	**15.9%**	**5.10**	**8.6%**	**6.0%**
st dev	*0.00*	*0.12*	*0.38*	*6.19*	*0.15*	*0.04*

Table 4-5: Summary of Data Comparisons

Project's D/IT use index category	Average Cost Growth	Average Schedule Growth	Average RIR	Average Change Cost Factor	Average Rework Factor
Contractors					
Top 10%	-7.5%	1.5%	1.54	-1.7%	3.7%
Top 25%	-1.4%	1.8%	2.29	2.3%	3.4%
no use	16.4%	6.3%	3.72	15.7%	8.4%
Owners					
Top 10%	1.4%	-1.3%	2.43	7.7%	5.6%
Top 25%	-2.8%	2.1%	2.14	12.8%	6.6%
no use	-0.3%	15.9%	5.10	8.6%	6.0%

For Tables 4-1 through 4-4, a total of twenty comparisons can be made between the average values for projects reporting high use of D/IT to those reporting no use. For example, in Table 4-1 the projects in the top 10% category had an average cost growth of –7.50% while those in the "no use" category had an average cost growth of 16.4 %. A total of seventeen out of twenty comparisons, including all ten of the contractor and seven of the owner averages, show better performance in the

high D/IT use index projects. A summary of these comparisons is shown in Table 4-5.

The first four tables also show the standard deviation values for each of the averages. For these values, thirteen of the twenty comparisons showed a lower standard deviation in the high D/IT use categories. The contractor's standard deviation values are lower in eight out of ten comparisons, and the owner's are lower in five out of ten.

The purpose of this analysis was to look at the "extremes" in regards to D/IT use. The projects in the middle are shown in the first four tables for completeness. When the same comparison is made between the middle and top categories, seventeen of twenty average values are better for the higher D/IT use index projects. For the standard deviation values, fifteen of the twenty were lower for the higher use categories.

It is important to note that since the owners are further removed from direct project impacts, it would be expected that their performance numbers would not be as closely tied to the use of D/IT. The numbers presented in the tables show this. Overall, 37 of the 40 comparisons for average and standard deviation values for the contractor values showed better performance numbers for the high D/IT use index projects. For a similar comparison of owner data, 25 out of 40 showed better performance numbers for the high D/IT use index projects.

While these data alone cannot support the assumption that a high use of D/IT will lead to improved project performance, it is a strong indication that a relationship

exits. The next step in this research was to select some of the projects with a D/IT use index in the top 25% for additional analysis.

Chapter 5: Bar Code Findings

The use of bar coding for the projects studied was mostly related to inventory control and employee badging. Although the technology has been available since the 1960's, its use in the construction industry has been limited.

Some of its benefits include:

- inventory tracking & control
- improved transaction processing time
- accurately inventory type & quantity descriptions
- paperwork reduction
- operating cost reduction

In this study, magnetic stripe usage was considered the same as bar code usage due to some of the respondents confusing the two and that their function was the same.

5.1 EXISTING DATA

In the D/IT practice section of CII's benchmarking and metrics questionnaire each respondent was asked whether or not bar coding was used. Furthermore, it lists five specific applications as shown in section 2.4 and in question 40d of Appendix A. An attempt was made to measure the level of use of each application. Depending on the level of use of each application, this section could contribute up to 1.25 points of the potential 10 points of the D/IT use index. Table 5-1 shows the score for each of the six projects selected for intense study.

Table 5-1: Bar Code Scores for the Six Exemplary Projects

Project	Bar Coding Score (maximum of 1.25)
O1	0.25
O2	0.19
O3	no use reported
C1	0.44
C2	0.38
C3	0.56

A sample calculation for this index is shown in Appendix C.

5.2 INTERVIEW DATA

During the interview each respondent was asked about the role of bar coding in their project and the perceived impacts of its use.

Reported uses in inventory control included supplier to project site tracking and some use in small parts bins. The principal items that were being coded and delivered to the site were structural steel and piping spools. Some of the respondents reported use by many of the suppliers and vendors, but did not have feedback on their use.

Only one contractor reported the use of the bar codes after the materials were received on site. An item, such as a pipe spool, would have its bar code scanned once it was fully installed. This provided expedient and accurate information to management personnel in tracking the job's progress. There were also plans to use this method for the inspection process.

5.3 LESSONS LEARNED

- Items that require finishing, such as galvanizing or painting structural steel presented a problem in that the tags had to be removed and reapplied as the components made their way from the manufacturer to the project site.
- When utilized for delivering materials, use was being driven by suppliers and contractors in an effort to improve services. This was also beneficial in the elimination of controversies over missing inventory.
- The biggest use was in tracking work hours of employees. This allows electronic tallying of total hours as well as categorization. However, with employee badging, it was reported that there were some instances in which some workers swiped their own, as well as another employees badge, when reporting to or departing from the work site.
- Sometimes it is beneficial for the paperwork, instead of the materials, to contain the bar code. It is easier to find the bar code, and it is less likely to be damaged or lost, however some efficiency and accuracy is lost. It still provides quicker and more accurate data input than traditional methods.
- Bar coding for small tool control has been successful in expediting the check out of tools and creating reports for tracking and use. This can be extremely important in providing management feedback on possible small tool shortages which can lead to decreased productivity rates.

- A contractor reported that one of its suppliers of pipe spools for a follow-on project did not use bar coding technology, but was still able to provide competitive pricing and services. He stated that the added price/piece for the bar codes was too high.

5.4 BAR CODING FUTURE

Some companies are benefiting from varied applications of bar coding technology, while others are getting along without it or with limited use. As with the adoption of most technologies, there is a cost in both hardware and employee training. A company must "slow down" and learn in order to become more proficient. However, those not using bar coding technology have a potential to further increase their competitive advantages by adopting its use.

Durability is an issue for bar codes attached to materials. The handling and transport process often leads to damaged or missing codes. Employee ID badges have overcome this by replacing the stick on labels with direct imprints on the badge. Improvements in the durability and attachment methods could benefit materials tracking.

Once the materials are delivered to the site, bar codes can help identify their placement and inspection. For example, if many roof top units (RTU's) are delivered to a site, bar codes could help in identifying a particular unit's placement, as well as provide information on its performance characteristics. A scanner plugged into a laptop could quickly provide the pertinent data. This application ties bar coding to the integrated database.

One company reported successful bar code use beyond delivery and acceptance of materials. Although they had not done so on the project that was being discussed, the company has successfully tracked materials on other jobs as they were installed by using bar codes. A foreman or work supervisor would scan in a particular piece after it was installed. This better enabled management to track work in place and plan future events. It also helped to calculate the percent of work complete for the job. The process of tracking materials through the installation and inspection process is one area in which bar coding can experience growth.

The successes experienced by the project managers shows that bar coding is contributing to the success of the project and its use will likely expand.

Chapter 6: Electronic Data Interchange Findings

Most of the reported uses of electronic data interchange (EDI) were identified as standard business practices such as when making fund transfers or providing a purchase order. The technology is used whenever it's available and the systems are compatible between users.

Overall, the use of EDI is increasing as users become more comfortable with its use and systems become more compatible. Better security in software systems is also enabling broader usage.

6.1 EXISTING DATA

In the D/IT practice section of CII's benchmarking and metrics questionnaire, the respondent was asked whether or not EDI was used. Furthermore, it lists five specific applications as shown in section 2.4 and in question 40b of Appendix A. An attempt was made to measure the degree of use for each application. Depending on the degree of use of each application, this section can contribute up to 1.25 points of the potential 10 points of the D/IT use index. Table 6-1 shows each project's score.

Table 6-1: EDI Scores for the Six Exemplary Projects

Project	EDI Score (maximum of 1.25)
O1	0.94
O2	0.50
O3	0.44
C1	0.81
C2	0.50
C3	0.69

A sample calculation for this index is shown in Appendix C.

6.2 INTERVIEW DATA

During the interview each respondent was asked about the role of EDI on their project and its perceived impacts.

Use in fund transfers and purchase orders were regarded as a standard administrative function. Interviewees lacked any detailed knowledge about most of the administrative aspects of their projects, but they did report that most of it was completed in an efficient manner.

An interesting application of this technology was in contractor/supplier alliances. Two of the respondents reported successes in this area with one reporting a "several hundred thousand dollar savings." In these alliances, a contractor forms a "partnering" arrangement with a supplier he has had favorable dealings with. The contractor can provide design information directly to the supplier who is better able to select the correct component. This saves the contractor design time and usually results in less over design.

One respondent reported using EDI for inspection reports with some of the vendors. This practice is growing as more vendors develop the capability.

6.3 LESSONS LEARNED

- The primary difficulties with EDI are system compatibility and user friendliness.
- Supplier alliances were used in order to achieve more efficient designs. The contractor or the owner provides the design criteria to the suppliers who are then better able to select the correct components. This leads to

less over-design with one contractor reporting savings in the magnitude of "several hundred thousand dollars."

- Supplier alliances were also reported to increase efficiency in material purchases. In these cases, the supplier receives electronic contract documents and was responsible for the quantity take-offs. Any excess material was the responsibility of the supplier, and the contractor and owner paid only for the actual quantities needed.
- Those not having their design specifications in electronic format realized the importance of doing so. Some have completed the conversion, while others reported that the process is ongoing.
- Respondents reported satisfaction with the transfer of inspection reports via e-mail attachments rather than using EDI. Most confused the two when answering the questionnaire.
- Those with the capability of using EDI for purchase orders and material releases were using it with continual success.
- A software upgrade by a user in the middle of a project can cause a temporary setback. One user reported that problems were encountered because of frequent software upgrades.
- One contractor was successful at overcoming an owner's fear of the contractor/supplier alliance. He was able to provide information substantiating the cost savings.

6.4 EDI FUTURE

EDI technology is justifiable for just about any size or type of construction project in at least a few of its basic applications. Lacking the capability or system incompatibility are the primary reasons its use has been limited. Software developers have the job to ensure the systems can transfer and properly read the data, and that the transactions are secure.

Alliances between contractors, owners, and suppliers should continue to grow. There will probably always be the issues of security and trust, but they can be overcome with solid long-term relationships. Alliances have proven their worth in improving efficiency in both cost and time savings.

Chapter 7: Integrated Database Findings

An integrated database was used for various applications on all six projects studied. During the interview, their use was discussed to determine successes and/or failures and how they contributed to the project. All respondents reported continual and expanding use of integrated databases. None of the respondents reported problems, which led to decreased or discontinued use.

Even though contractors are not generally competing with the owners, some of the respondents indicated that there is some concern that sensitive data could be exposed.

7.1 EXISTING DATA

In the D/IT practice use section of CII's benchmarking and metrics questionnaire the respondent was asked whether or not an integrated database was used. Furthermore, it lists eight specific applications as shown in section 2.4 and in question 40a of Appendix A. An attempt is made to measure the level of use of each application. Depending on the application use, this section can contribute up to 2 points of the potential 10 points of the D/IT use index. Table 7-1 shows each project's score.

Table 7-1: Integrated Database Scores for the Six Exemplary Projects

Project	Integrated Database Score (maximum of 2.00)
O1	0.94
O2	no reported use
O3	0.69
C1	1.38
C2	1.19
C3	1.38

A sample calculation for this index is shown in Appendix C.

Some of the respondents indicated they did not fully understand the definition of an integrated database. In some instances, this accounted for a lower index score.

7.2 INTERVIEW DATA

During the interview each respondent stated that the use of the integrated database was expanding as more software packages are able to exchange data. In some cases, the organizations are developing their own software "adapters" which tie different commercial software packages together.

Perhaps the most important finding in this area was the impact of the international planning and design efforts. In these arrangements, the project development and design phases are completed through an international team effort of designers and project management personnel. Figure 7-1 is a graphical representation of the process.

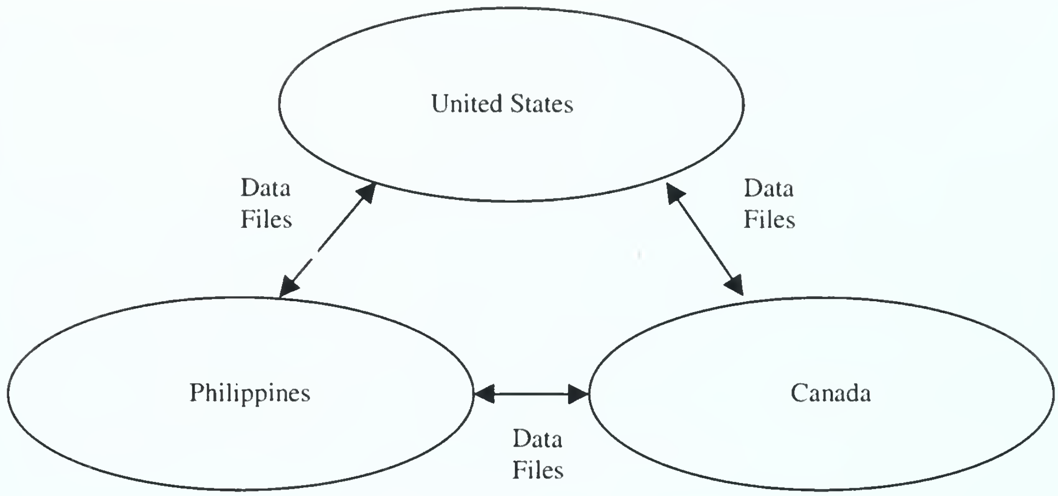


Figure 7-1: Diagram of International Design Team Data Transfer

In this example, the owner/contractor team from the United States works with firms from other countries. The principal reason for this team arrangement is cost savings from the lower labor rates overseas. By using a shared database, information in the form of drawing and text files can be easily accessed by every member of the team. This practice, along with video teleconferencing, has greatly reduced the number of out-of-town trips.

Before these technologies were available, the owner organization would provide its own employees to sit in the overseas offices to help coordinate the efforts. The extra costs associated with these arrangements often offset much of the savings.

For one of the owner projects studied, the savings created by this arrangement was credited with making it financially feasible. In 1990, the project was terminated early in the planning stages because it was too costly. However, in 1995 the owner

organization approached one contractor it had previous dealings with and requested assistance with reviving the project. The idea of an international design effort was proposed, and the associated cost reduction was the principal reason the project could move forward. The project was a success and the facility is currently in operation.

Another project utilized a design team comprised of a U.S./Mexico team that was credited with substantial savings. Both respondents indicated that more of their future work would be completed in this manner.

7.3 LESSONS LEARNED

- An integrated database is a key element in cost savings for international design efforts.
- When an international effort is conducted, there is a potential for schedule compression since one company's working hours are the same as another company's "sleep" hours.
- Companies need to have electronic files of the information that is pertinent to planning and design efforts. This includes, but is not limited to, design specifications, company building requirements and safety policies. It is important that these files be kept current and accessible by all individuals who need the information.
- The integrated database must be properly integrated with 3D CAD to derive all of the benefits. The easier that various personnel can access the model, the smoother the operation.

7.3.1 Reported problems

The primary problems associated with the use of integrated databases are compatibility and software upgrades. Often, contractor and owner personnel have different software packages, and time is expended in one organization learning the others system. Even when using the same software, one companies updated version often causes a glitch when the other has not yet updated its system. This is similar to some of the problems with EDI.

In addition, updating software during a project's execution can cause some delay as personnel learn the new and/or expanded features. This sometimes leads to frustration and a user's reluctance to use the system.

7.4 INTEGRATED DATABASE FUTURE

More intersystem compatibility and user friendliness would increase the use of this technology. Good business demands that costs associated with setting up the technology and training personnel to use it cannot exceed the benefits received. The more costly and difficult the system is to use, the less likely it will be used.

The primary challenge in creating an integrated database is creating a system that will integrate all functions. This is due to software incompatibility and differing company procedures. Resolving software compatibility and communications issues is an ongoing process. However, getting organizations to perform individual functions in the same manner is not very likely. The software must be adaptable to varying business practices.

Increasing the use of the security and read-only capabilities of the software will further advance the use of the integrated database. This requires that the users are knowledgeable in terms of the system's capability and having the assurance that their sensitive data is protected.

Chapter 8: 3-Dimensional CAD Findings

The technology studied for this thesis that is reported to have the greatest impact on cost, schedule, rework, and possibly safety is 3D CAD modeling. One of the biggest advantages is in the ability of the software to do interference checking in more areas of the design. The savings in rework and the associated time and cost reductions have been well documented. For the projects studied, this technology was first used to model only the structural steel and large bore piping as these items made up the bulk of the design. However, the success of their use in the model has led to the incorporation of many other elements including small bore pipe, electrical conduits and cable trays, lighting, concrete, tanks, and other process equipment. The challenge here is to balance the cost of including these elements in the CAD model with the associated cost savings.

Visualization is another area in which the model has a significant impact. This is equally important in the planning as well as the construction phase. Users are reporting increased use in this area, as more project personnel are becoming comfortable with the model and use it to visualize details. The recent versions of the 3D modeling software are easier to use.

8.1 EXISTING DATA

In the D/IT practice use section of CII's benchmarking and metrics questionnaire, each respondent was asked whether or not a 3D CAD model was used. It lists twenty-two applications as shown in section 2.4 and in question 40c of Appendix A. An attempt is made to measure the level of use of each application.

Depending on the use, this section can contribute up to 5.50 points of the potential 10 points of the D/IT use index. Table 8-1 shows each projects score.

Table 8-1 3D CAD Scores for the Six Exemplary Projects

Project	3D CAD Score (maximum of 5.50)
O1	3.25
O2	1.75
O3	4.25
C1	2.00
C2	2.38
C3	2.81

A sample calculation for this index is shown in appendix C.

8.2 INTERVIEW DATA

Most of the discussion during the interview was centered on the benefits and uses of 3D CAD. Reductions in rework were recognized as the biggest time and money savers. Companies are finding it beneficial to include smaller elements of the design into the model. One company reported that rework was reduced by a factor of 10, from six percent down to less than one-half percent. Since most respondents had different ways of tracking rework, it was impossible to make accurate comparisons in this category. However, the other projects reported similar reductions between the days before 3D CAD was first introduced.

Modeling of the components of the design has grown from including just structural steel and piping to the inclusion of just about every element. Users reported the following in their latest models:

structural steel
piping

electrical conduits, raceways, and cable trays
instrumentation "bubbles"
lighting
tanks, pumps, and other process equipment
stairways and handrails
site work
concrete
clearance zones for equipment and personnel

One contractor was using vendor-supplied drawings and scanning the diagrams into the computer for inclusion into the 3D model.

8.3 LESSONS LEARNED

- One of the most valuable applications of the 3D modeling software is checking for interferences in all areas of the design. All respondents reported that this has significantly reduced the amount of rework by factors ranging from 5-10 in terms of man-hours. The rates are decreasing as more elements are included in the model.
- Keeping as-builts current is important for future expansions to the project. Although there are added costs associated with this, one company reported success in doing this for a follow-on addition project. The costs saved by not having to revise and update the old model equaled the extra costs of keeping the model-up-to-date.
- Cycle time was reduced by being able to start more work simultaneously. For example, prior to the use of 3D CAD, much of the large diameter pipe would have to be erected before conduits and cable trays could be

installed. With these elements shown in the model, they can be built simultaneously with less worry regarding interferences.

- More components can be fabricated in the shop because the 3D-model shows placement and clearances that were previously unknown prior to actual construction. This provides both cost and schedule advantages.
- The need for plastic models is virtually eliminated. This is a significant savings that offsets some of the costs to develop the model as one typically costs between $100K-200K for the types of industrial projects in this study. One respondent indicated that only one plastic model had been built since the adoption of 3D CAD. This was for an overseas project in which the owner insisted on having one.
- Precise material take-offs are generated from the drawings. The model is able to provide a listing of required materials and their quantity. This has resulted in cost savings as much of the excess material was either sent back at a reduced credit, or simply piled up as leftovers which may or may not be used. One company reported a 30% saving in electrical materials because of this application.
- One contractor documented a $5M savings on a $230M project from adopting the use of 3D CAD. This was a different project than the one that was being discussed.
- Contractors who have the capability to work with different programs have a competitive advantage. This is because owners usually require that

contractors use their software package. The principal software packages used on the studied projects are Intergraph Plant Design System (PDS) and Autocad Plant Applications and Systems for Concurrent Engineering (PASCE).

- When performing computer simulations of crane lifts in 3D, it is important that all components be in the model. One contractor reported omitting a few of the "smaller" pieces attached to a process reactor. The simulation went smooth, but a few pieces had to be cut off of the reactor during the lift.
- A 3-month time savings during the construction phase was attributed to the simulated lifting of a process reactor in the 3D model. The crew knew precisely which pieces could be installed on the reactor and would not cause problems in the lift. This resulted in the ability to perform more work on the reactor while it was in the vertical position.
- The ability to take portions of the model and electronically send them to fabricators is another time and money savings feature. First, the electronic files are downloaded to the fabrication shop. Next, the shop's computer generates the isometric fabrication drawings and corresponding materials lists. This information can be sent back electronically for the contractor's designers to review.

8.4 3D CAD FUTURE

The integration of CAD and computer-aided engineering is one area in which this technology is expected to further advance. Some software companies are already doing this. For example, a software package that can design structural elements from user input loads and dimensional constraints could export its design data directly into a 3D model that has other elements of the design.

Use of 3D CAD for non-industrial projects is also important and will likely continue to grow as familiarity increases and costs related to the technology are reduced. In addition to the industrial plants studied here, building designs can benefit greatly if all components are modeled in 3D. For example, if electrical conduits and piping are shown in the drawings at the correct scale instead of merely lines, other elements of the design are more likely to be sized correctly to accommodate them.

It's only a matter of time before virtually all construction designs are completed in three dimensions. Being able to "see" the finished product in a virtual world has many advantages, and it will continue to reduce changes and design conflicts.

Chapter 9: Conclusions & Recommendations

The technologies discussed in this report are still in the early stages of implementation in the construction industry. However, companies are using them successfully and are continuing to find ways to improve project performance by expanding their use of design and information technologies.

9.1 CONCLUSIONS

- The design and information technologies studied here have proved to be valuable resources in improving project performance in terms of reductions in cost and schedule growth, and by reducing rework and change orders.
- The data shows that projects with high D/IT index had better safety records that those with a low index. This is probably due to the fact that the organizations that are using these technologies also have more progressive management and safety programs. However, one project manager felt that the increased use of simulated crane lifts in 3D is making a positive impact on his company's safety record.
- Contractors are using D/IT more than owners. Only 42 of 114 (37%) contractors have a D/IT use index of less than 1.0 while 100 of 183 (55%) owners have an index of less than 1.0.
- Management continually benefits from the accurate and timely information that D/IT provides. This improves communication and provides an opportunity for better planning and shortened schedules.

- Although these D/IT tools have traditionally been in the hands of management and design personnel, they are spreading into more areas as more workers become familiar with computers and their software is easier to use.
- The ease of operating D/IT software packages and costs associated with their implementation have a significant effect on whether they are used. Most projects have a tight budget and schedule, and companies are reluctant to "slow down" to implement a new technology without having a firm grasp on its benefits.
- Some companies are operating competitively without the use of these technologies, while others have proven their worth. This suggests there is an opportunity for a greater competitive advantage among the non-users.
- Although many of the technologies discussed in this research have been available for several years, their use has been limited in the construction industry. The D/IT use index average is lower than all other CII practice index averages.

Although it is difficult to directly relate some of the applications of these technologies to quantifiable performance, it's interesting to note some of the claims made regarding the overall success for the projects studied in this research. One of the project managers reported that his project set a safety record for both the owner and the contractor for the lowest recordable incident rate (RIR). Another project manager reported the lowest design hours/piece that his organization had ever

experienced. Still another project manager reported cost savings beyond anyone's expectations.

The challenge for owners and contractors is to successfully adopt and integrate all of the applications as well as train their personnel in a cost-effective manner. As the suppliers of these technologies improve their system's compatibility and user friendliness, their use should spread which will further reduce their costs.

Another lesson learned is in regards to the CII questionnaire. While analyzing the CII database, it was noted that many of the projects indicated no use of design and information technology. The number of projects reporting no use are shown in Table 9-1.

Table 9-1: Summary Data for Projects Reporting No D/IT Use

Project respondent	Number of projects	Projects reporting no use	Average cost of the projects which reported no use
Contractor	114	21	$8.85M
Owner	183	53	$28.15M

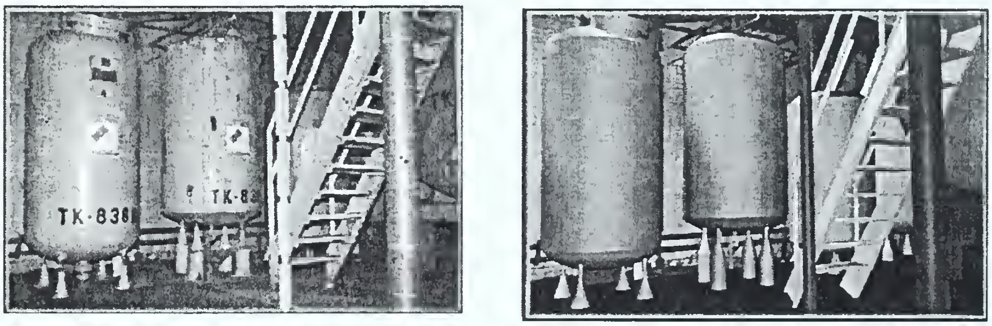
Given the widespread use of technology practices such as electronic fund transfers and integrated databases, it is unlikely that the number of projects had no use of the CII listed D/IT practices. Most of the interviewees were not clear on the definitions of some of the applications in the questionnaire.

9.2 RECOMMENDATIONS

CII should address applications of D/IT that are not listed in its questionnaire. Some of the organizations are using other applications and are likely to be achieving the same successes as with the applications contained in the CII questionnaire. One

application of 3D modeling which is not in the questionnaire and was discussed during an interview with one of the contractors is photogrammetry. An example is shown in Figure 9-1. Another example is computer aided engineering. These technologies should be studied to determine their impacts on the industry.

Figure 9-1: Example of the Use of Photogrammetry



In addition, revisions to the CII questionnaire are necessary to ensure that the questions are answered accurately so that correlations between D/IT usage and project performance, as well as comparisons between projects, can be better made.

Since most of the findings in this research are for to the heavy industrial construction industry, a study similar to this one should be done that focuses in on other industries, specifically commercial and/or residential buildings

Finally, a computer related study in which personnel from construction and owner companies who are responsible for the computers and their applications would be helpful in identifying the needs in this area. It would also help to include information about the latest software and future developments. The end product should be a compilation of information regarding different software strengths and

weaknesses as well as their compatibility with other systems. This could help construction organizations determine which system could work best for them.

Appendix A: Contractor Questionnaire

Appendix A is a sample of CII's version 3.0 questionnaire that is sent to contractors. The owner version has only slight differences, but is identical in the D/IT section.

The data collected by this form begins the third round of data collection for CII's benchmarking and metrics system. The data will be used to establish performance norms, to identify trends, and to correlate execution of project management processes to project outcomes. It will form part of a permanent database. Through such correlation across many companies and projects, opportunities for improving your company's project performance will be identified. Following the data collection and metrics calculations, each company will be provided project and company aggregate key reports for comparison with the database benchmarks. It is important that you retain a copy of this questionnaire for your records and future analysis. **All data will be held in strict confidence.**

When you have completed the questionnaire, please return it to your Company's Benchmarking Associate by **June 1, 1998.**

The next 2 pages contain definitions for project phases. Please pay particular attention to the start and stop points highlighted. All project costs should be given in U.S. dollars. If you need further assistance in interpreting the intent of a question, please call Steve Thomas CII at (512) 232-3007 (E-mail: sthomas@mail.utexas.edu) or Marvin Oey CII at (512)232-3051 (E-mail: marvinoey@mail.utexas.edu). Conformance to the instructions and phase definitions is crucial for establishing reliable benchmarks.

Your Company Benchmarking Associate has been provided with a list of projects that were submitted by your company during the previous data collection effort. To maintain the integrity of the database, please ensure that projects that were submitted previously are not reported again.

If the information required to answer a given question is not available, please write "UNK" (unknown) in the space provided. If the information requested does not apply to this project, please write "NA" (not applicable) in the space provided. Keep in mind, however, that too many "unknowns" or "not applicables" could render the project unusable for analysis.

CII Benchmarking and Metrics
Contractors (Version 3.0)

1. Your Company: ______________________________

2. Your Project I.D. ____________ (You may use any reference to protect the project's identity. The purpose of this I.D. is to help you and CII personnel identify the questionnaire correctly if clarification of data is needed and to prevent duplicate project entries.)

3. Project Location: Domestic ______________________________, USA
State
International ______________________________
Country

4. Contact Person (name of the person filling out this form): ______________________________

5. Contact Phone No. (____) ____________ **6.** Contact Fax No. (____) ____________
E-mail address ______________________________

7. Principal Type of Project

Check only one. If you feel the project does not have a principal type, but is an even mixture of two or more of those listed, please attach a short description of the project. If the project type does not appear in the list, please describe in the space next to "Other.":

Industrial	Infrastructure	Buildings
______Electrical (Generating)	______Electrical Distribution	______Lowrise Office
______Oil Exploration/Production	______Highway	______Highrise Office
______Oil Refining	______Navigation	______Warehouse
______Pulp and Paper	______Flood Control	______Hospital
______Chemical Mfg.	______Rail	______Laboratory
______Environmental	______Water/Wastewater	______School
______Pharmaceuticals Mfg.	______Airport	______Prison
______Metals Refining/Processing	______Tunneling	______Hotel
______Consumer Products Mfg.	______Mining	______Parking Garage
______Natural Gas Processing		______Retail
______Automotive Mfg.		
______Foods		

______Other (Please describe)______________________________

8. This project was (check only one): Grass Roots_____ Modernization _____ Addition _____

Grass roots - a new facility from the foundations and up. A project requiring demolition of an existing facility before new construction begins is also classified as grass roots.

Modernization - a facility for which a substantial amount of the equipment, structure, or other components is replaced or modified, and which may expand capacity and/or improve the process or facility.

Addition - a new addition that ties in to an existing facility, often intended to expand capacity.

______ Other (Please describe)______________________________

9. Please indicate if the Owner of this project is a CII member or non-member company. The last page of the glossary contains a CII membership list.

CII Benchmarking and Metrics
Contractors (Version 3.0)

CII Member _____
non-member _____

10. Please indicate in the table below the function(s) **your company** performed on this project and the approximate percent of each to the nearest 10%. For each function, indicate the principle form of remuneration in use at the completion of the work. Also indicate if your contract contained incentives. Use a separate line for each function your company performed.

Please use the following codes to identify the **Function(s)** performed by your company.

PPP	Pre-Project Planner	DM	Demolition Contractor
PPC	Pre-Project Planning Consultant	GC	General Contractor
D	Designer	PC	Prime Contractor
PE	Procurement - Equipment	SC	Subcontractor
PB	Procurement - Bulks	PM	Project Manager
		CM	Construction Manager

Percent of Function refers to the percent of the overall function contributed by your company. Estimate to the nearest 10 percent.

Type of Remuneration refers to the overall method of payment. Unit price refers to a price for in place units of work and does not refer to hourly charges for skill categories or time card mark-ups. Hourly rate payment schedules should be categorized as cost reimbursable. Please use the following codes to identify remuneration type.

LS	Lump Sum	CR	Cost Reimbursable/Target Price
UP	Unit Price	GP	Guaranteed Maximum Price

If **Incentives** were utilized in your companys' contract, please indicate whether those incentives were positive (a financial incentive for attaining an objective), negative (a financial disincentive for failure to achieve an objective), or both. Circle "+" to indicate a positive incentive and circle "-" to indicate a negative incentive.

Function	Approx. Percent of Function (Nearest 10%)	Type of Remun. (Contract End)	Contract Incentives (circle as many as apply)							
			Cost		Schedule		Safety		Quality	
			+	-	+	-	+	-	+	-
			+	-	+	-	+	-	+	-
			+	-	+	-	+	-	+	-
			+	-	+	-	+	-	+	-
			+	-	+	-	+	-	+	-

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10A. Is your company an ***Alliance Partner*** with the owner of this project?

Yes ______________________ No ____

- An alliance partner is a company with whom your company has a long-term formal strategic agreement that ordinarily covers multiple projects.

11a. Your company's *Project Budget at Authorization to Proceed*.

- This is the estimated cost at authorization to proceed for your company's portion of the project only (not the budget for the entire project). If possible, do not include corporate overhead.
- Do not include profit.
- Be sure to include the cost of work performed by your subcontractors.
- **Do not** include the estimated cost of change orders granted while the project was underway (these are examined in question 15)
- State your company's project budget in U.S. dollars to the nearest $1000. (You may use a "k" to indicate thousands in lieu of "...,000".)

$ __________

11b. How much ***contingency*** does this budget contain? (to the nearest $1000. You may use a "k" to indicate thousands in lieu of "...,000".)

$____

12. Your company's *Total Actual Project Cost*:

- This is the actual cost of your company's portion of the project only (not the total cost of the entire project). If possible, do not include corporate overhead.
- Do not include profit.
- **Include** the cost of executing change orders.
- State your companys' Total Actual Project Cost in U.S. dollars to the nearest $1000. (You may use a "k" to indicate thousands in lieu of "...,000".)

$______________________________

12a. Does the project budget and project cost given above include any general (non-project) corporate overhead?

UNK ____ Yes ________ No _______

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13. Please indicate **your company's** budget and actual costs by project phase

- Phase budget amounts should correspond to **your company's budget** at authorization to proceed. Do not include the estimated cost of change orders in the "Phase Budget" column. These are addressed in question 15. However, the "Actual Phase Cost" column should include all project costs, including those attributable to change orders.
- Refer to the table on pages 2 and 3 for phase definitions and typical cost elements.
- Include the cost of bulk materials in construction and the cost of engineered equipment in procurement.
- If your company did not perform any function during a project phase, check "NA" for that phase.
- The sum of phase budgets should equal your company's budget at authorization to proceed and the sum of actual phase costs should equal your company's total actual cost reported in questions 11a & 12 above.)

Project Phase	NA	Phase Budget (Including Contingency)	Amount of Contingency in Budget	Actual Phase Cost
Pre-Project Planning		$	$	$
Detail Design		$	$	$
Procurement		$	$	$
Demolition/Abatement		$	$	$
Construction		$	$	$
Startup		$	$	$
Totals		$	$	$

14. Please indicate **your company's** Planned and Actual Project Schedule

- The dates for the planned schedule should be those in effect when you were authorized to proceed. If you cannot provide an exact day for either the planned or actual, estimate to the nearest week in the form mm/dd/yy; for example, 1/8/96, 2/15/96, or 3/22/96.
- Refer to the chart on pages 2 and 3 for a description of starting and stopping points for each phase.
- If your company did not perform any function during a project phase, check "NA" for that phase.

Project Phase	NA	Planned Schedule		Actual Schedule	
		Start mm / dd / yy	Stop mm / dd / yy	Start mm / dd / yy	Stop mm / dd / yy
Pre-Project Planning		/ /	/ /	/ /	/ /
Detail Design		/ /	/ /	/ /	/ /

Procurement		/ /	/ /	/ /	/ /
Demolition/Abatement		/ /	/ /	/ /	/ /
Construction		/ /	/ /	/ /	/ /
Startup		/ /	/ /	/ /	/ /

15. ***Project Development Changes*** and ***Scope Changes.*** Please record the changes **to your contract** by phase in the table provided below. For each phase indicate the total number, the **estimated** net cost, and the **estimated** net schedule impact resulting from project development changes and scope changes. The estimates of cost and schedule impact should be those amounts approved by the owner or its agent and incorporated in change orders. Do not include profit. (The actual costs and durations of change orders should be included in your response to questions 12, 13, & 14.)

Project Development Changes include those changes required to execute the original scope of work or obtain original process basis.

Scope Changes include changes in the base scope of work or process basis.

- Changes should be included in the phase in which they were initiated. Refer to the table on pages 2 and 3 to help you decide how to classify the changes by project phase. If you cannot provide the requested change information by phase, but can provide the information for the total project please indicate the totals.

- Write "NA" in the first column for any phase in which your company did not perform work.

- Indicate "minus" (–) in front of cost or schedule values, if the net changes produced a reduction. If no change orders were granted during a phase, write "0" in the "Total Number" columns.

- State the estimated cost of changes in U.S. dollars to the nearest $1000 and the estimated schedule changes to the nearest week. You may use a "k" to indicate thousands in lieu of "...,000".

Project Phase	Total Number of Project Development Changes	Total Number of Scope Changes	Net Cost Impact of Project Development Changes ($)	Net Cost Impact of Scope Changes ($)	Net Schedule Impact of Project Development Changes (weeks)	Net Schedule Impact of Scope Changes (weeks)
Design			$	$	wks	wks
Procurement			$	$	wks	wks
Demolition/Abatement			$	$	wks	wks
Construction			$	$	wks	wks
Startup			$	$	wks	wks
Totals			$	$	wks	wks

16. Field Rework

Was there a system for tracking and evaluating your company's field rework for this project? Check N/A if your company was not involved in the construction phase.

_____ Yes _____ No _____ N/A

If yes, please complete the following table. If no or N/A, proceed to question 17b.

Please indicate the Direct Cost of Field Rework, the Cost of Quality Management, and the Schedule Impact of Field Rework for each category shown in the following table. If you track field rework by a few other or additional categories, please add them in the blank spaces provided. If the system used on this project does not include any of the Sources of Field Rework listed, write "NA" (not applicable) in the Direct Cost of Field Rework space. If your system used a listed Source of Field Rework, but this project had no Field Rework attributable to it, write "0" in the Direct Cost of Field Rework space. If you cannot provide the requested field rework information by Source of Field Rework, but can provide the information for the total project, please write "UNK" (unknown) in the fields adjacent to the sources of field rework and indicate the totals.

The ***direct cost of field rework*** relates to all costs needed to perform the rework itself whereas the ***cost of quality management*** includes quality assurance or quality control costs, which may identify the need to perform field rework or prevent the need for additional field rework.

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Source of Field Rework	Direct Cost of Field Rework	Cost of Quality Management	Schedule Impact of Field Rework
Owner Change	$	$	Weeks
Design Error / Omission	$	$	Weeks
Designer Change	$	$	Weeks
Vendor Error / Omission	$	$	Weeks
Vendor Change	$	$	Weeks
Constructor Error / Omission	$	$	Weeks
Constructor Change	$	$	Weeks
Transportation Error	$	$	Weeks
	$	$	Weeks
	$	$	Weeks
	$	$	Weeks
Totals	$	$	Weeks

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17. Actual Total Cost of Major Equipment

Please record the actual total cost of major equipment procured for permanent installation in this project in the space provided below.

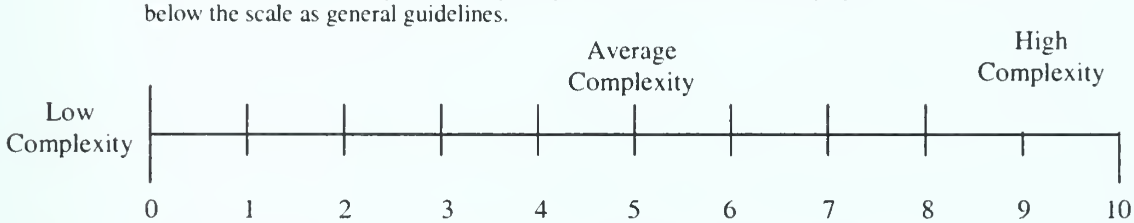
- Include only the invoiced cost for items of major equipment. Do not include the cost of associated services such as making vendor inquiries, analyzing vendor bids, or expediting.
- State the cost of equipment in U.S. dollars to the nearest $1000. You may use a "k" to indicate thousands in lieu of "...,000".
- Refer to the following table to help you identify major equipment expenditures.
- If the project did not include major equipment, which is typical of many infrastructure or building projects, please write "NA."

$ ____

General Classification	**Kinds of Equipment Covered**
Columns and Pressure Vessels (Code Design)	Towers, columns, reactors, unfired pressure vessels, bulk storage spheres, and unfired kilns; includes internals such as trays and packing.
Tanks (non-code design; 0-15 psig, MAW or design pressure)	Atmospheric storage tanks, bins, hoppers, and silos.
Exchangers	Heat transfer equipment: tubular exchangers, condensers, evaporators, reboilers, coolers (including fin-fan coolers and cooling towers) - excludes fired heaters.
Direct-fired Equipment	Fired heaters, furnaces, boilers, kilns, and dryers, including associated equipment such as super-heaters, air preheaters, burners, stacks, flues, draft fans and drivers, etc.
Pumps	All types of liquid pumps and drivers.
Vacuum Equipment	Mechanical vacuum pumps, ejectors, and other vacuum-producing apparatus and integral auxiliary equipment.
Turbines	
Motors	
Electricity Generation and Transmission	Major electrical items (e.g., transformers, switch gear, motor-control centers, batteries, battery chargers, and cable [15kV]).
Speed Reducers/Increasers	
Materials-Handling Equipment	Conveyers, cranes, hoists, chutes, feeders, scales and other weighing devices, packaging machines, and lift trucks.
Package Units	Integrated systems bought as a package (e.g., air dryers, refrigeration systems, ion-exchange systems, etc.).
Special Processing Equipment	Agitators, crushers, pulverizers, blenders, separators, cyclones, filters, centrifuges, mixers, dryers, extruders, and other such machinery with their drivers.

17b. **Project Complexity**

Place a mark anywhere on the scale below that best describes the level of complexity for this project as compared to other projects from the same industry sector. For example, if this is a heavy industrial project, how does it compare in complexity to other heavy industrial projects. Use the definitions below the scale as general guidelines.



- **Low Complexity -** Characterized by the use of no unproven technology, small number of process steps, small facility size or process capacity, previously used facility configuration or geometry, proven construction methods, etc.

- **High Complexity -** Characterized by the use of unproven technology, an unusually large number of process steps, large facility size or process capacity, new facility configuration or geometry, new construction methods, etc.

18. **Workhours and Accident Data**

Please record the total craft workhours, the number of recordable injuries, and the number of lost workday cases for your company and your subcontractors separately in the spaces provided below.

- Use the U.S. Department of Labor's OSHA definitions for recordable injuries and lost workday cases among this project's craft workers. If you do not track in accordance with these definitions, write "UNK" in the recordable injuries and lost workday cases columns.

- Circle "Unk" provided in each box for which the information is unavailable or incomplete. Circle "NA" if your company was not involved in the construction phase or provided inspection services only.

- A consolidated project OSHA 200 log is the best source for the data.

	Total Field Workhours	OSHA Recordable Injuries	OSHA Lost Workday Cases
Your Direct-Hire Craft Employees			
Subcontractor Craft Employees			

18a. How many of your direct-hire craft employee workhours reported in the table above were "overtime" (or "premium time")?

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Safety Practices

Safety includes the site-specific program and efforts to create a project environment and state of consciousness which embraces the concept that all accidents are preventable and that zero accidents is an obtainable goal.

If your company was not involved in the construction phase, go to question 36.

	Yes	No	
19.	___	___	This project had a written site-specific safety plan.
20.	___	___	This project had a written site-specific emergency plan.
21.	___	___	This project had a site safety supervisor.
22.	___	___	The site safety supervisor for this project was full-time.
23.	___	___	This project had a written safety incentive program for hourly craft employees.
24.	___	___	Toolbox safety meetings were required.
25.	___	___	This project required prehire substance abuse testing of contractor employees.
26.	___	___	Contractor employees were randomly screened for alcohol and drugs.

If this project was accident free, check "NA" as appropriate for questions 27 through 30.

27. Substance abuse tests were conducted after an accident:

______ Always ______ Sometimes ______ Seldom ______ Never

28. Accidents were formally investigated:

______ Always ______ Sometimes ______ Seldom ______ Never

29. Near-misses were formally investigated:

______ Always ______ Sometimes ______ Seldom ______ Never

30. Senior management reviewed accidents:

______ Always ______ Sometimes ______ Seldom ______ Never

31. Safety was a high priority topic at all pre-construction and construction meetings:

______ Always ______ Sometimes ______ Seldom ______ Never

32. Safety records were a criterion for contractor/subcontractor selection:

______ Always ______ Sometimes ______ Seldom ______ Never

33. Pre-task planning for safety was conducted by contractor foremen:

______ Always ______ Sometimes ______ Seldom ______ Never

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34. Jobsite-specific orientation was conducted for new contractor and subcontractor employees:

______ Always   ______ Sometimes   ______ Seldom   ______ Never

35. Place a mark anywhere on the scale below that best describes the owner's commitment to safety on this project. Judge this owner's commitment relative to that of owners with whom you have experience.

Low   Average   High

0 1 2 3 4 5 6 7 8 9 10

Team Building Practices

<u>Team Building</u> is a process that brings together a diverse group of project participants and seeks to resolve differences, remove roadblocks and proactively build and develop the group into an aligned, focused and motivated work team that strives for a common mission and for shared goals, objectives and priorities.

36. Was your company involved in a team building process that included owner personnel on this project?

Yes ______   No ______

If yes, answer questions 36a - 36h. If no, go to question 37.

Yes   No

36a. ____ ____ Was an independent consultant used to facilitate the team building process?

36b. ___ ___ Was a team-building retreat held early in the life of the project?

36c. ___ ___ Did this project have a documented team-building implementation plan?

36d. ___ ___ Were objectives of the team building process documented and clearly defined?

36e. Were team building meetings held among team members throughout the project?

_______ Regularly   _______ Sometimes   _______ Seldom

36f. Were follow-up sessions held to integrate new team members and reinforce concepts?

_______ Regularly   _______ Sometimes   _______ Seldom

36g. Please indicate the project phases in which your company was involved in the team building process?

____ Pre-Project Planning   ____ Construction
____ Design   ____ Startup
____ Procurement

36h. Please indicate the parties involved in the team building process?

____ Owner
____ Designer(s)
____ Contractor(s)
____ Major Suppliers
____ Subcontractor(s)
____ Construction Manager
____ Other. If other, please specify ______________________________

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Constructability Practices

Constructability is the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives. Constructability is achieved through the effective and timely integration of construction input into planning and design as well as field operations. If your company was not involved in the constructability process check "Unknown."

37. Was Constructability implemented on this project? Yes _____ No ______ Unknown _

If yes, please respond to the following statements (37a-37l). If no or unknown, go to question 38.

37a. Which of the following best describes the constructability program designation for this project?

____ No designation
____ Part of standard construction management activities
____ Part of another program, such as Quality or only identified on a project level
____ Recognized on a corporate level, but may be part of another program
____ Stand-alone program on same level as Quality or Safety

37b. Which of the following best describes the constructability training of personnel for this project?

____ None
____ If any occurs, done as on-the-job training
____ Awareness seminar(s)
____ Part of standard orientation
____ Part of standard orientation; deeply ingrained in corporate culture

37c. Which of the following best describes the role of the constructability coordinator for this project?

____ Coordinator not identified
____ Part-time if identified; very limited responsibility
____ Informal full- or part-time position; responsibilities vary
____ Formal full- or part-time position; responsibilities vary
____ Full-time position; plays major project role

37d. Which of the following best describes the constructability program documentation for this project?

____ None; CII documents may be available
____ Limited reference in any manual; CII documents may be distributed or referenced
____ Project-level constructability documents exist; may be included in other corporate documents
____ Project constructability manual is available
____ Project constructability manual is thorough, widely distributed, and periodically updated

37e. Which of the following best describes the nature of project-level efforts and inputs concerning constructability for this project?

____ None
____ Reactive approach, constrained by review mentality, poor understanding of proactive benefit
____ Aware of major benefits, proactive approach

____ Proactive approach; routinely consult lessons learned
____ Aggressive, proactive approach from beginning of project; routinely consult lessons learned

37f. Which of the following best describes the implementation of constructability concepts on this project?

____ Very little concept implementation
____ Some concepts used periodically; often considered too late to be of use
____ Selected concepts applied regularly; full use, timeliness of input varies
____ All concepts consistently considered; timely implementation of feasible concepts
____ All concepts consistently considered, continuously evaluated, aggressively implemented

37g. Constructability ideas on this project were collected by:

_____ Suggestion Box
_____ Interviews
_____ Review Meetings
_____ Questionnaire
_____ Other Methods ____
_____ Not Collected

37h. To what extent was a computerized constructability database utilized for this project?

_____ None
_____ Minimal
_____ Moderate
_____ Extensive

37i. Please characterize the frequency of the constructability reviews and discussions for this project.

_____ Once a Week
_____ Once a Month
_____ Once every 3 Months
_____ Once every 6 Months
_____ Once a Year or Less Frequent

37j. Please indicate the time period of the first meeting that deliberately and explicitly focused on constructability. Place a check below the appropriate period.

Pre-Project Planning			Detail Design/Procurement			Construction		
Early	Middle	Late	Early	Middle	Late	Early	Middle	Late

Choose only one.

Yes No

37k. ___ ___ Constructability was an element addressed in this project's formal written execution plan.

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37l. ___ ___ Were the actual cost savings (identified cost savings less implementation cost) due to the constructability program tracked on this project?

If yes, please list? $ ________________

Pre-Project Planning Practices

Pre-Project Planning involves the process of developing sufficient strategic information with which owners can address risk and decide to commit resources to maximize the chance for a successful project. Pre-project planning is often perceived as synonymous with front-end loading, front-end planning, feasibility analysis, and conceptual planning.

38. Did your company participate in the pre-project planning effort? (Check only one of 38a, 38b, or 38c)

38a. ___ Yes, as the pre-project planner. Please continue with question 38d.

38b. ___ Yes, as a consultant (to the owner or to another firm that performed pre-project planning for the owner). Please continue with question 38d.

38c. ___ No, my company did not participate in the pre-project planning. Go to question 39.

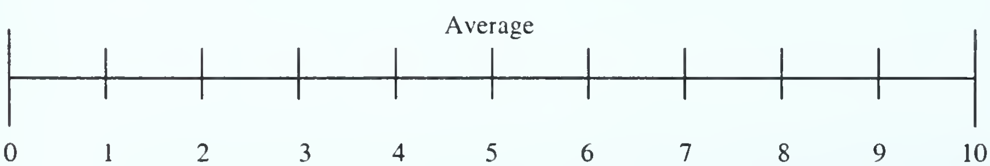
38d. Did your company formally assess the quality of the pre-project planning effort?

Yes ______

No

Please respond to the following statements using the definitions provided below the scale for guidance.

38e. Place a mark on the scale below that best describes the composition of the pre-project planning team.



- **Excellent** - Highly skilled and experienced members with authority; representation from business, project management, technical disciplines, and operations; able to respond to both business and project objectives.
- **Poor** - Members with a poor combination of skill or experience that lack authority; insufficient representation from business, project management, technical disciplines, and operations; unable to respond to both business and project objectives.

38f. Place a mark on the scale below that best describes the technology evaluation for this project.

Poor — Average — Excellent

0 1 2 3 4 5 6 7 8 9 10

- **Excellent** - Thorough and detailed identification and analysis of existing and emerging technologies for feasibility and compatibility with corporate business and operations objectives. Scale-up problems and hands-on process experience were considered.
- **Poor** - Poor or no technology evaluation.

38g. Place a mark on the scale below that best describes the evaluation of alternate siting locations.

Poor — Average — Excellent

0 1 2 3 4 5 6 7 8 9 10

- **Excellent** - Thorough and detailed assessment of relative strengths and weaknesses of alternate locations to meet owner requirements.
- **Poor** - Poor or no evaluation of alternate siting locations.

38h. Place a mark on the scale below that best describes the risk analysis performed for project alternatives.

Poor — Average — Excellent

0 1 2 3 4 5 6 7 8 9 10

- **Excellent** - Risks associated with the selected project alternatives were identified and analyzed. These analyses included financial/business, regulatory, project, and operational risk categories in order to minimize the impacts of risks on project success.
- **Poor** - Poor or no risk analysis performed for project alternatives.

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The Project Definition Rating Index (PDRI) identifies and describes critical elements in a scope definition package and allows a project team to predict factors impacting project risk. A PDRI has been developed for Industrial Projects and for General Building Projects (in developement, Spring 1998). It is intended to evaluate the completeness of project scope definition prior to consideration for authorization.

39. Was the Project Definition Rating Index (PDRI) utilized on this project? _____ yes _____ no

If yes, indicate which PDRI was used to score this project . _____ Industrial _____ Building

If yes, indicate the score received just prior to total project budget authorization. _________ Please attach a copy of the PDRI scoresheet and proceed to question 40.

If no, please ***complete the appropriate matrix*** on the following pages. The first matrix applies to industrial projects while the second matrix applies to general building projects. If you are unsure of which matrix is appropriate ***use the matrix that best fits***. It is also acceptable to complete both matrices.

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Industrial Projects Matrix for Question 39 (PDRI)

Please complete the following matrix using the appropriate definition levels given below. Definition is provided for each of the pre-project planning elements on pages 4 through 11 of the glossary of terms. <u>Indicate how well defined each element was prior to the total project budget authorization by placing a check below the appropriate definition level</u>. Elements with definition levels 2 through 4 darkened should be answered as "yes/no" questions. Indicate definition level 1 for "yes" or definition level 5 for "no" to indicate if the elements either existed or did not exist within the project definition package at authorization.

Definition Levels:

1 - Complete definition
3 - Some deficiencies
5 - Incomplete or poor definition
2 - Minor deficiencies
4 - Major deficiencies
N/A - Not applicable

Note: If this is an infrastructure project some of the following elements may not apply to your project. Please place a check in the "N/A" column to indicate "not applicable" if any element does not apply to your project.

	Definition Level at Authorization					
Industrial Projects	Complete				Poor	
Technical Elements	1	2	3	4	5	N/A
a. Process Flow Sheets						
b. Site Location						
c. P&ID's						
d. Heat & Material Balances						
e. Environmental Assessment						
f. Utility Sources With Supply Conditions						
g. Mechanical Equipment List						
h. Specifications - Process/Mechanical						
i. Plot Plan						
j. Equipment Status						
Business Elements						
k. Products						
l. Capacities						
m. Technology						
n. Processes						
o. Site Characteristics Available vs. Req'rd						
p. Market Strategy						
q. Project Objectives Statement						
r. Project Strategy						
s. Project Design Criteria						
t. Reliability Philosophy						
Execution Approach Elements						
u. Identify Long Lead/Critical Equip. & Matl's						
v. Project Control Requirements						
w. Engineering/Construction Plan & Approach						

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General Building Projects Matrix for Question 39 (PDRI)

Please complete the following matrix using the appropriate definition levels given below. Definition is provided for each of the pre-project planning elements on pages 4 through 11 of the glossary of terms. Indicate how well defined each element was prior to the total project budget authorization by placing a check below the appropriate definition level. Elements with definition levels 2 through 4 darkened should be answered as "yes/no" questions. Indicate definition level 1 for "yes" or definition level 5 for "no" to indicate if the elements either existed or did not exist within the project definition package at authorization.

Definition Levels:

1 - Complete definition
3 - Some deficiencies
5 - Incomplete or poor definition
2 - Minor deficiencies
4 - Major deficiencies
N/A - Not applicable

Note: If this is an infrastructure project some of the following elements may not apply to your project. Please place a check in the "N/A" column to indicate "not applicable" if any element does not apply to your project.

General Building Projects	Definition Level at Authorization					
	Complete				Poor	
Technical Elements	1	2	3	4	5	N/A
a. Circulation and Open Space Requirements						
b. Site Location						
c. Functional Relationship Diagram / Room by room						
d. Stacking Diagrams						
e. Environmental Asessment						
f. Utility Sources with Supply Conditions						
g. Room Data Sheets						
h. Design Standards						
i. Civil/Geotechnical Information						
j. Permitting, Reg., & Code Compliance Plan						
Business Elements						
k. Building Use						
l. Facility Parameters						
m. Value Analysis Process						
n. Design Philosophy						
o. Facility Characteristics						
p. Business Justification						
q. Project Objectives Statement						
r. Business Plan						
s. Project Design Criteria						
t. Reliability Philosophy						
Execution Approach Elements						
u. Identify Long Lead/Critical Equip. & Matl's						
v. Project Control Requirements						
w. Design/Engineering/Construction Plan & Approach						

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Design/Information Technology Practices

Please place a check to indicate the extent to which each design/information technology application listed below was used on this project. See the legend below for definition of the "Use Levels." If you believe that an application could not have been appropriately applied on this project check "N/A." If your company was not involved with the project function(s) in which an application is generally used, please check "Unk" for that application.

Use Levels:
1 - Extensive Use 3 - Moderate Use 5 - No Use Unk - Unknown
2 - Much Use 4 - Little Use N/A - Not applicable

40a. Was an ***integrated database*** utilized on this project? Yes _____ No _____ Unk_____

If yes, please indicate the extent that each of the following shared data within the integrated database. If other applications were used, please list them. If no, proceed to question 40b.

	Use Levels						
	Extensive Use				No Use		
Applications	1	2	3	4	5	N/A	Unk
Facility planning							
Design / Engineering							
3D CAD model							
Procurement / Suppliers							
Material management							
Construction operations / Project controls							
Facility Operations							
Administrative / Accounting							

40b. Was ***electronic data interchange (EDI)*** utilized on this project?
Yes ______
No ______
Unk ______

If yes, please indicate the extent to which each of the following document types were transmitted using EDI. If other applications were used, please list them. If no, proceed to question 40c.

	Use Levels						
	Extensive Use				No Use		
Applications	1	2	3	4	5	N/A	Unk
Purchase orders							
Material releases							
Design specifications							
Inspection reports							

Fund transfers							

40c. Was ***3D CAD modeling*** utilized on this project?

Yes ______
No ______
Unk ______

If yes, please indicate the extent to which a 3D CAD model was used for each of the following applications. If other applications were used, please list them. If no, proceed to question 40d.

	Use Levels						
	Extensive Use					No Use	
Applications	1	2	3	4	5	N/A	Unk
Define / communicate project scope							
Perform plant walk-throughs (Replacing plastic models)							
Perform plant operability / maintainability analyses							
Perform constructability reviews with design team							
Use as reference during project / coordination meetings							
Work breakdown and estimating							
Plan rigging or crane operations							
Check installation clearances / access							
Plan and sequence construction activities							
Construction simulation / visualization							
Survey control and construction layout							
Material management, tracking, scheduling							
Exchange information with vendors / fabricators							
Track construction progress							
Visualize project details or design changes							
Record "As-Built" conditions							
Train construction personnel							
Safety assessment / training							
Plan temporary structures (formwork, scaffolding, etc.)							
Operation / Maintenance training							
Turn-over design documents to the project owner							
Start-up planning							

40d. Was ***bar coding*** utilized on this project?

Yes ______
No ______
Unk ______

If yes, please indicate the extent to which bar coding was used for each of the following applications. If other application were used, please list them. If no, proceed to question 41.

CII Benchmarking and Metrics
Contractors (Version 3.0)

	Use Levels					No Use	
	Extensive Use						
Applications	1	2	3	4	5	N/A	Unk
Document control							
Materials management							
Equipment maintenance							
Small tool / consumable material control							
Payroll / Timekeeping							

CII Benchmarking and Metrics
Contractors (Version 3.0)

Project Change Management Practices

Change Management focuses on recommendations concerning the management and control of both *scope changes* and *project development changes*.

Please check the appropriate response for the questions below. If your company was not involved with the project function(s) in which a practice element is generally used, please write "UNK" for that question.

Yes No

41a. ___ ___ Was a formal documented change management process, familiar to the principal project participants used to actively manage changes on this project?

41b. ___ ___ Was a baseline project scope established early in the project and frozen with changes managed against this base?

41c. ___ ___ Were design "freezes" established and communicated once designs were complete?

41d. ___ ___ Were areas susceptible to change identified and evaluated for risk during review of the project design basis?

41e. ___ ___ Were changes on this project evaluated against the business drivers and success criteria for the project?

41f. ___ ___ Were all changes required to go through a formal change justification procedure?

41g. ___ ___ Was authorization for change mandatory before implementation?

41h. ___ ___ Was a system in place to ensure timely communication of change information to the proper disciplines and project participants?

41i. ___ ___ Did project personnel take proactive measures to promptly settle, authorize, and execute change orders on this project?

41j. ___ ___ Did the project contract address criteria for classifying change, personnel authorized to request and approve change, and the basis for adjusting the contract?

41k. ___ ___ Was a tolerance level for changes established and communicated to all project participants?

41l. ___ ___ Were all changes processed through one owner representative?

41m. ___ ___ At project close-out, was an evaluation made of changes and their impact on the project cost and schedule performance for future use as lessons learned?

41n. ___ ___ Was the project organized in a Work Breakdown Structure (WBS) format and quantities assigned to each WBS for control purposes prior to total project budget authorization?

This concludes the questionnaire; please review your responses and ensure you have answered all questions. Thank you for your participation. Please return this questionnaire to your Benchmarking Associate.

Appendix B: D/IT and Metrics Definitions

The D/IT definitions are included with the CII questionnaire.

DESIGN/INFORMATION TECHNOLOGIES

Bar Coding. The use of automatic identification technology by labeling, identifying, and controlling items, materials, and equipment through the use of bar codes. A bar code can be defined as a self-contained message with information encoded in the widths of bars and spaces in a printed pattern.

Electronic Data Interchange (EDI). EDI is a technology that permits the direct computer-to-computer exchange of data in a standard format. Data is transmitted in a standard industry format, checked for error, and imported directly into the receiving computer system without re-keying.

Integrated Database. An integrated database is a concept of organizing, storing, and managing all electronic data relating to a project in such a fashion that data is entered and stored once and then accessed and utilized by multiple users and applications. The users may include those involved with facility planning, design, procurement, construction, plant operations, and suppliers.

3D CAD modeling. Computer aided drafting system that provides three dimensional views for checking physical interferences in addition to providing two and three dimensional drafting capabilities.

METRICS

Design/Information Technology Use Index – This number represents a company's level of use of the D/IT applications listed in the CII questionnaire. It ranges from 0 to a maximum of 10 depending on the number of applications used and the extent of their use.

Project Cost Growth – This number represents the percentage of cost increase that the project experienced as compared to the original budget.

Project Schedule Growth – This number represents the percentage of schedule growth that the project experienced as compared to what was originally planned.

Recordable Incident Rate (RIR) – This Occupational and Safety Health Administration (OSHA) defined term represents any occupational injuries or illnesses which result in:

- Fatalities, regardless of the time between the injury and death, or the length of the illness; or
- Lost workday cases, other than fatalities, that result in lost workdays; or
- Nonfatal cases without lost workdays which result in transfer to another job or termination of employment, or require medical treatment (other than first aid) or involve loss of consciousness or restriction of work or motion. This category also includes any diagnosed occupational illnesses that are reported to the employer but are not classified as fatalities or lost workday cases. (OSHA Regulations (Standard - 29 CFR)).

Rework Factor – This number represents a percentage of costs for field rework as compared to the actual cost for the construction phase of the project. This includes all rework regardless of initiating cause.

Cost Change Factor - This number represents a percentage of costs for scope and project development changes as compared to the actual total project cost.

Appendix C: Design/Information Technology Index Calculation

A summated rating scale was used by CII to calculate the practice use indices. The index is based on a scale of one to ten.

The following example shows how the design/information technology use index is calculated from a respondents answers to the CII questionnaire. In the example, fictitious responses to the practice use are underlined.

Design/Information Technology Practice Use

Question	Yes	No
40a. Was an *integrated database* utilized on this project?	**X**	

Applications	Use Levels						
	Extensive use			No Use			
	1	2	3	4	5	N/A	*Score*
Facility planning	1.00	0.75	**0.50**	0.25	0.00	0.00	0.50
Design / Engineering	1.00	0.75	0.50	0.25	0.00	0.00	0.00
3D CAD model	1.00	0.75	0.50	**0.25**	0.00	0.00	0.25
Procurement / Suppliers	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Material management	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Construction operations / Project controls	1.00	0.75	**0.50**	0.25	0.00	0.00	0.50
Facility Operations	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Administrative / Accounting	1.00	0.75	0.50	0.25	0.00	0.00	0.00

Question	Yes	No
40b. Was an *electronic data interchange (EDI)* utilized on this project?	**X**	

Applications	Use Levels						
	Extensive use			No Use			
	1	2	3	4	5	N/A	*Score*
Purchase orders	1.00	0.75	**0.50**	0.25	0.00	0.00	0.50
Material releases	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Design specifications	1.00	0.75	0.50	**0.25**	0.00	0.00	0.25
Inspection reports	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Fund transfers	**1.00**	0.75	0.50	0.25	0.00	0.00	1.00

Question	Yes	No
40c. Was *3D CAD modeling* utilized on this project?	**X**	

Applications	Use Levels						
	Extensive use			No Use			
	1	2	3	4	5	N/A	*Score*
Define / communicate project scope	1.00	0.75	**0.50**	0.25	0.00	0.00	0.50
Perform plant walk-throughs (Replacing plastic models)	1.00	0.75	0.50	**0.25**	0.00	0.00	0.25
Perform plant operability / maintainability analyses	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Perform constructability reviews with design team	1.00	0.75	**0.50**	0.25	0.00	0.00	0.50
Use as reference during project / coordination meetings	1.00	**0.75**	0.50	0.25	0.00	0.00	0.75
Work breakdown and estimating	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Plan rigging or crane operations	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Check installation clearances / access	1.00	**0.75**	0.50	0.25	0.00	0.00	0.75
Plan and sequence construction activities	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Construction simulation / visualization	1.00	0.75	0.50	**0.25**	0.00	0.00	0.25
Survey control and construction layout	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Material management, tracking, scheduling	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Exchange information with vendors / fabricators	1.00	0.75	**0.50**	0.25	0.00	0.00	0.50
Track construction progress	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Visualize project details or design changes	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Record "As-Built" conditions	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Train construction personnel	1.00	0.75	0.50	**0.25**	0.00	0.00	0.25
Safety assessment / training	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Plan temporary structures (formwork, scaffolding, etc.)	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Operation / Maintenance training	1.00	0.75	**0.50**	0.25	0.00	0.00	0.50
Turn-over design documents to the project owner	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Start-up planning	1.00	0.75	0.50	0.25	0.00	0.00	0.00

Question	Yes	No
40d. Was *bar coding* utilized on this project?	**X**	

Applications	Use Levels						
	Extensive use			No Use			
	1	2	3	4	5	N/A	*Score*
Document control	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Materials management	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Equipment maintenance	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Small tool / consumable material control	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Payroll / Timekeeping	1.00	**0.75**	0.50	0.25	0.00	0.00	0.75

TOTAL	8.00
40 questions, maximum score of 40 - divide total by 4 to scale to 1-10 point range	
Design/Information technology Use Index	**2.00**

Appendix D: Contractor and Owner Data

Appendix D consists of two tables, one for contractor project data and one for owner project data. The projects shown in italics represent the cut-off point for the projects which are in the top 25% of the D/IT use index.

Contractor Project Summary Data

CII Project ID	D/IT Use Index	Project Cost Growth	Project Schedule Growth	RIR	Change Cost Factor	Rework Factor
C191	8.23	-0.196	0.171	1.56		0.017
C326	7.99	-0.251	-0.027	5.59	-0.277	
C176	7.58	-0.008	-0.038	0.32	0.000	0.036
C193	7.03	-0.022	0.365	1.95	0.064	0.016
C195	7.03	0.047	-0.054	0.00	0.076	0.030
C392	6.62	0.047	-0.048	1.23	0.067	0.034
C147	6.25	0.059	-0.313	2.76	-0.010	0.000
C388	5.94	0.005	0.010	0.93	0.109	
C214	5.30	0.014	0.000	0.34	0.028	0.041
C418	5.12	-0.795	0.040	1.11	-0.250	0.121
C137	5.06	0.277	0.062	1.10	0.028	
C215	4.94	-0.007	0.205		0.094	0.000
C389	4.66	-0.010	0.011		0.011	
C375	4.56	0.012	-0.051	2.84	0.080	0.018
C394	4.55	-0.111	0.030	1.74	-0.063	0.047
C192	4.30	-0.085	-0.464	0.90		0.012
C153	4.09	-0.078	-0.060	6.59		0.022
C148	4.05	-0.011	-0.035	2.53	-0.003	0.017
C128	3.86	-0.089	0.000	4.00		
C311	3.85	0.348	0.067	1.11	0.057	0.023
C416	3.75	-0.049	-0.046	2.89	0.030	0.064
C138	3.54	-0.012	0.000	0.00	0.003	0.005
C179	3.44	0.113	0.315		0.107	
C310	3.44	-0.113	0.162		0.181	
C381	3.43	0.238	0.000		0.064	
C131	3.31	0.169	0.129	11.62	0.138	0.119
C157	3.11	0.094	-0.083	1.00	0.006	
C412	3.06	0.035	0.159	0.46	0.016	0.022
C390	***2.88***	***-0.133***	***0.037***	***1.11***	***-0.039***	***0.022***
C305	2.81	-0.045	0.000	0.58		0.056
C373	2.75	0.183	0.047	1.09	0.084	0.028
C158	2.56	0.078	0.000		0.375	
C361	2.50	0.184	0.000		0.143	
C411	2.43	-0.009	0.066	0.97	0.096	0.003
C188	2.31	-0.012	0.042	3.86		0.025
C159	2.20	0.116	0.047	2.45	0.112	0.015
C194	2.19	-0.081	-0.157		-0.028	
C309	2.15	-0.171	0.000	0.00	-0.009	0.014
C323	2.13	-0.031	0.400		0.544	
C415	2.12	0.077			0.091	
C328	2.04	0.091	0.048		0.058	

C329	2.04	0.077	0.000		0.098	
C307	2.00	-0.093	0.000		0.043	
C168	1.96	0.108	0.061		0.079	2.062
C173	1.96	-0.080	-0.029		0.088	
C151	1.91	0.193	-0.041	5.84	0.053	0.022
C160	1.81	-0.053	0.041	1.09	0.074	0.012
C149	1.77	0.252	0.079	18.50	0.042	0.015
C145	1.72	0.107	0.046	2.40	0.109	0.049
C185	1.67	-0.290	0.000	1.66	0.033	
C304	1.67	0.007	0.000		0.070	
C397	1.67	-0.171	0.077	0.00	0.003	0.046
C362	1.64	-0.014	0.075			
C213	1.63	-0.134	0.000		-0.074	
C347	1.56	0.008	-0.083		0.215	
C129	1.52	0.275	0.079	7.16	0.214	
C200	1.52	0.193	-0.173	2.68	0.137	0.247
C330	1.44	0.388	0.089	0.00	0.105	0.016
C413	1.43	0.283	0.161		0.158	
C139	1.41	-0.073	0.250	0.00		0.419
C127	1.40	0.063	0.130	9.83	0.125	0.028
C170	1.34	-0.068	-0.103		0.005	
C417	1.32	0.093	0.880	0.53	0.081	
C319	1.29	-0.022	-0.020	0.61	-0.017	
C165	1.25	0.710	1.042		0.348	
C199	1.25	-0.404	-0.158		0.010	
C163	1.19	0.006	0.020	2.50	0.067	
C359	1.19	-0.041	0.000	0.00	0.244	
C187	1.16	0.104	0.049	1.54	0.101	0.009
C393	1.09	0.110	0.000	1.56	0.110	0.287
C306	1.03	0.135	0.013	5.00	0.149	
C378	1.03	0.267	0.056		0.194	
C216	0.91	0.047	0.000	0.00	0.000	0.031
C339	0.90	0.202	0.038	1.23	0.202	
C178	0.88	0.089	-0.060		0.082	
C338	0.88	0.051	-0.036	0.00	0.199	0.008
C398	0.81	-0.098	0.000	0.00		0.109
C167	0.77	0.267	0.590		0.192	
C156	0.75	-0.029	0.192	14.55	0.300	
C318	0.72	1.006	0.056	1.49	0.274	
C130	0.66	0.933		4.83	0.483	
C321	0.65	0.232	0.102		0.278	
C171	0.64	0.175	-0.091		0.216	
C376	0.64	0.702	0.000	14.86	0.652	
C377	0.63	0.792	-0.034	15.86	0.085	0.005
C142	0.56	0.584	0.000		0.364	
C220	0.46	0.003	0.062	0.00	0.003	

C324	0.41	0.093	0.000		0.085	
C132	0.37	0.117	0.161		0.102	
C317	0.28	-0.048	0.224	0.00	0.007	0.011
C342	0.28	0.128	0.324	0.00	0.114	0.115
C169	0.24	-0.157	0.144	1.20	0.012	0.059
C370	0.24	1.189	0.156		0.517	
C143	0.00	0.036	0.070	8.00	0.122	
C177	0.00	0.131	0.281		0.116	
C181	0.00	-0.181	0.000	0.00	0.062	
C182	0.00	0.396	0.600	0.00	0.376	
C172	0.00	0.131	0.019	0.00	0.186	
C198	0.00	3.180	-0.021		0.679	
C196	0.00	0.330	0.080		0.124	
C152	0.00	0.018	0.000	4.38	0.032	
C154	0.00	-0.066	0.233		0.098	
C218	0.00	0.160	0.033	6.52	0.138	
C314	0.00	-0.200	-0.136		0.084	
C315	0.00	0.140	-0.018	0	0.009	0.241
C316	0.00	0.107	0.115	5.79		0.078
C343	0.00	-0.609	0.000	97.01	0.588	0.001
C363	0.00	0.069	0.017		0.064	
C371	0.00	0.003	0.069	7.98	0.044	0.048
C372	0.00	0.111	0.207	1.46	0.128	0.051
C374	0.00	-0.049	-0.077	8.57	0.021	
C349	0.00	-0.078	0.00	5.84	0.050	
C350	0.00	-0.135	-0.091	3.49		
C391	0.00	-0.059	-0.060	0.00	0.062	

Owner Project Summary Data

CII Project ID	D/IT Use Index	Project Cost Growth	Project Schedule Growth	RIR	Change Cost Factor	Rework Factor
O188	7.88	0.121	0.114	1.21	0.103	0.067
O398	6.97	-0.037	-0.041	0.00	0.141	0.000
O370	5.75	-0.181	0.074	0.09	0.019	0.006
O311	5.50	0.347	0.375	1.91		0.042
O415	5.38	-0.055	-0.088	0.73		0.006
O313	5.25	0.234		0.79		
O143	5.24	-0.157	-0.090	0.80		0.025
O307	5.19	-0.048	0.161	4.70	0.089	0.004
O349	5.19	0.083	-0.014	0.50	0.086	0.007
O433	5.00	-0.048	0.000	5.71	0.096	0.300
O359	4.73	-0.200	0.000	0.00	0.023	0.036
O155	4.63	0.007	-0.022	0.83		

O434	4.63	0.121		4.80	0.062	0.106
O139	4.31	-0.074	-0.077	0.80		0.009
O435	3.97	0.135		0.00	0.007	
O182	3.95	-0.111				
O345	3.95	0.00	-0.213		0.177	0.170
O432	3.85	0.123	-0.358	16.00	0.048	0.011
O141	3.64	-0.032	-0.111		-0.010	
O317	3.57	-0.096	0.000	0.00		
O346	3.50	-0.013	0.281	0.00	0.085	
O116	3.46	0.318	0.167	1.32	0.022	0.041
O180	3.40	0.083				
O431	3.38	-0.002	-0.049	13.33	0.014	
O364	2.94	-0.190	0.167	0.00	0.005	0.071
O117	2.92	-0.161	-0.177	0.00	0.215	0.040
O412	2.89	0.077	-0.146		0.087	0.094
O132	2.86	-0.056	0.000	8.15	0.019	0.007
O408	2.82	-0.015	-0.086		0.144	0.179
O108	2.81	-0.020	-0.077	1.30		
O361	2.56	-0.322	0.333		0.062	0.087
O115	2.44	-0.188	-0.072	1.45	0.002	0.020
O160	2.44	0.115	0.000	0.00	0.088	0.082
O362	2.44	-0.236	0.141	0.00	0.001	0.030
O138	2.43	0.231	0.000		0.159	
O358	2.43	-0.505	0.000	0.00	2.181	
O372	2.43	-0.218	0.000	0.00	0.049	0.163
O410	2.19	-0.006	0.092		0.090	
O123	2.13	-0.071	-0.032	1.67	0.038	
O149	2.13	-0.001	-0.227	0.00		
O172	2.06	0.055	0.348		0.066	
O161	2.04	-0.084	-0.133	3.22	0.015	0.049
O175	1.88	-0.015	0.393	2.46	0.086	0.143
O162	1.83	0.066	0.000	0.00	0.059	0.000
O357	1.83	-0.223	0.028	3.07	0.045	
O312	***1.79***	***-0.034***	***0.189***	***2.34***	***0.121***	***0.105***
O385	1.79	-0.072	0.000	2.52	0.069	0.113
O110	1.67	0.093	-0.163	10.50	0.183	
O368	1.65	-0.276	0.000			0.090
O339	1.64	-0.124	-0.085	0.00	-0.052	
O379	1.60	-0.012	0.208		0.070	0.090
O400	1.59	0.152	0.000	59.60	0.951	
O342	1.56	-0.035	-0.170	0.00	0.048	
O344	1.56	0.049	0.041	2.51	0.151	0.056
O350	1.56	0.005	0.197	0.31	0.035	
O369	1.50	-0.264	0.000		0.006	0.077
O170	1.46	-0.044	1.889	0.00		
O366	1.44	-0.238	0.000			0.039

O158	1.31	0.000	0.000	0.00	0.081	
O157	1.31	0.000	0.000	0.00	0.041	
O338	1.31	-0.121	0.020	2.39	0.019	0.001
O145	1.29	-0.033	0.092		0.113	0.116
O105	1.25	-0.195	0.066	2.17	0.034	0.085
O179	1.25	-0.031	0.076	6.74	0.024	0.063
O190	1.25	-0.255	-0.082		0.053	
O340	1.25	-0.185	-0.020	17.05	-0.038	0.013
O351	1.25	-0.096	-0.076	1.86	0.016	0.057
O404	1.25	-0.156	0.151		0.094	
O176	1.22	-0.110	0.000	2.75	0.024	
O113	1.16	0.235	0.115			
O308	1.11	0.025	0.063	0.00	0.174	
O124	1.10	0.027	-0.022	10.27	0.113	
O129	1.10	0.098	0.136	2.95	0.089	
O373	1.09	0.004	0.000	0.00		
O374	1.09	0.209	0.000	0.00		
O375	1.09	-0.088	0.000			
O376	1.09	-0.067	-0.107			
O378	1.09	-0.168	-0.250			
O130	1.07	0.045	-0.306	6.77		0.041
O318	1.06	0.042	0.075	9.33	0.086	0.005
O413	1.03	-0.042	0.295		0.055	
O309	1.01	-0.037	-0.055			0.028
O401	1.00	-0.022	0.007		0.036	0.003
O377	0.94	0.042	0.273	0.00	0.040	
O388	0.94	0.128	0.106	1.28	0.052	0.108
O127	0.91	0.058	-0.149	0.00	0.060	
O363	0.86	-0.111	0.516	0.00	0.101	0.066
O365	0.86	-0.045	0.000			0.047
O107	0.83	0.007	0.000	0.63		0.018
O409	0.79	-0.010	0.179		0.032	0.010
O106	0.77	-0.071	0.406	3.92	0.018	0.115
O304	0.75	0.064	-0.128	2.14	0.012	0.034
O305	0.75	0.009	-0.098	1.90	0.015	0.029
O164	0.72	-0.017	0.327	0.00	0.039	0.007
O347	0.69	0.250	0.048	3.02		0.033
O166	0.67	0.093	0.231	0.00	0.160	
O137	0.67	-0.325	-0.016	0.00	0.085	
O174	0.63	0.334	0.125	1.73	0.014	0.077
O360	0.58	0.142	0.329	0.00		0.011
O411	0.58	-0.103	0.335		0.028	
O135	0.56	-0.004	0.000	1.06	0.063	0.012
O122	0.56	0.000	0.575	4.26	0.096	
O169	0.55	-0.169	0.022	4.21	0.003	0.017
O150	0.50	0.470	0.283	0.00	0.295	0.045

O181	0.50	0.017				
O389	0.50	0.012	0.033	3.51	0.017	0.086
O403	0.50	-0.015	0.192	0.00	0.062	0.073
O118	0.46	-0.171	-0.054	7.35		
O153	0.41	0.001	0.057	1.94	0.001	0.034
O386	0.39	-0.013	0.000	0.81	0.032	
O125	0.37	0.026	-0.008	7.56		
O195	0.37	-0.216	0.318		0.117	
O301	0.34	-0.161	-0.118	0.00		
O159	0.26	0.077	0.000	4.91	0.159	
O393	0.25	0.487	0.473	22.23	0.208	
O394	0.25	-0.041	3.794	0.00	0.001	0.089
O396	0.25	-0.028	0.141	0.00	0.024	
O428	0.25	0.104		5.48	0.016	
O429	0.25	-0.041	3.794	0.00	0.001	0.089
O430	0.25	0.487	0.473	22.23	0.208	
O189	0.24	0.063	0.517	0.00		
O302	0.24	-0.152			0.051	
O173	0.19	0.083	0.000			
O383	0.19	0.00	0.008		0.002	
O154	0.18	-0.100	0.000	8.32	0.075	0.017
O151	0.18	0.060	14.750	0.00	-0.014	0.011
O133	0.14	0.005	-0.160	2.02	0.013	
O184	0.12	-0.030	0.015			
O177	0.08	0.293				
O306	0.07	-0.006	0.170	0.00	-0.001	
O103	0.00	-0.026	0.107	2.13	0.064	0.113
O109	0.00	-0.134	0.102	0.00	0.005	0.036
O111	0.00	0.022	-0.080	11.05	0.071	
O112	0.00	-0.033	0.164	16.06		
O134	0.00	0.322	0.000		0.093	0.052
O126	0.00	-0.036	0.497	12.60		
O128	0.00	0.029	0.186	1.60	0.042	
O131	0.00	0.103	-0.791			
O144	0.00	-0.072	0.092			
O142	0.00	0.035		0.00	0.001	
O140	0.00	-0.005	0.000	0.00	-0.005	0.056
O152	0.00	-0.078	0.103	14.47	0.022	
O156	0.00	-0.098	-0.163	0.00		
O119	0.00	0.547	0.187	0.00	0.348	
O121	0.00	-0.034	1.063	0.00		
O163	0.00	-0.088	-0.031		0.060	0.027
O168	0.00	-0.230	-0.217	4.17		
O178	0.00	0.024	0.673	0.00	0.118	0.143
O136	0.00	-0.027	0.146	0.00	0.086	
O104	0.00	-0.019	0.000	1.96	0.035	

O183	0.00	0.054	0.719			
O185	0.00	-0.002	0.718		0.021	
O186	0.00	0.048	-0.288			
O187	0.00	0.037	0.839		0.064	
O191	0.00	0.042	1.710		0.042	
O192	0.00	0.021	0.030		0.043	
O193	0.00	0.047	0.109		0.051	
O194	0.00	-0.052	0.013		0.011	
O300	0.00	-0.152		0.00	0.037	
O303	0.00	0.000	-0.089	0.00		
O310	0.00	0.063	0.046	0.00		0.082
O315	0.00	0.086		9.18	0.018	
O316	0.00	-0.008		15.02	0.053	0.106
O319	0.00	-0.030	-0.103	8.48	0.053	
O341	0.00	-0.141	0.000	21.58	0.058	
O343	0.00	0.028	0.173	7.30		
O348	0.00	-0.087	0.067		0.186	
O371	0.00	-0.062	0.450		0.011	0.117
O380	0.00	-0.081	0.000		0.842	0.007
O381	0.00	0.203	0.108		0.137	
O382	0.00	0.010	0.000		0.020	
O384	0.00	-0.094	0.000	0.00	0.055	
O387	0.00	-0.080		0.00	0.029	
O390	0.00	-0.011	-0.077	8.57	0.017	0.022
O391	0.00	-0.012	0.000	7.82		
O392	0.00	-0.005	0.192	5.56	0.070	
O397	0.00	-0.089	0.075		0.005	0.023
O399	0.00	0.103	-0.019		0.046	
O402	0.00	-0.014	0.167		0.040	0.015
O367	0.00	-0.087	0.057		0.009	
O405	0.00	-0.108	0.325		0.175	
O406	0.00	0.000	0.117	10.56	0.042	0.045
O414	0.00	0.010	0.240	0.00	0.359	

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Vita

John Darnell Spencer was born in San Gabriel, California on May 1, 1967, the son of Connie Josephine Spencer and Calvin Darnell Spencer. After graduating from Westminster High School in Westminster, California in 1985, he entered Cypress College in Cypress, California and completed the requirements for an A.S. degree in general engineering in the fall of 1988. After two quarters of study at Cal Poly Pomona, he transferred to Cal Poly in San Luis Obispo, California and received a degree in mechanical engineering in 1991. He then entered the Civil Engineer Corps of the United States Navy, completing Officer Candidate School in Newport, Rhode Island and reporting for duty in the Public Works Department at Naval Air Station Memphis in 1992. His work assignments included facilities planning, engineering design, and management of base maintenance contractor personnel. His next assignment was at the Navy's construction contract office at the Naval Air Weapons Station, China Lake, California where he worked from December 1995 to July 1998. There, he was responsible for the administration of grass roots and renovation projects ranging from $2K to $16M. While there, he passed the professional engineering exam and was registered in the state of California. In August of 1998 he entered The Graduate School at the University of Texas at Austin under the Navy's post-graduate education program. He currently holds the rank of Lieutenant.

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